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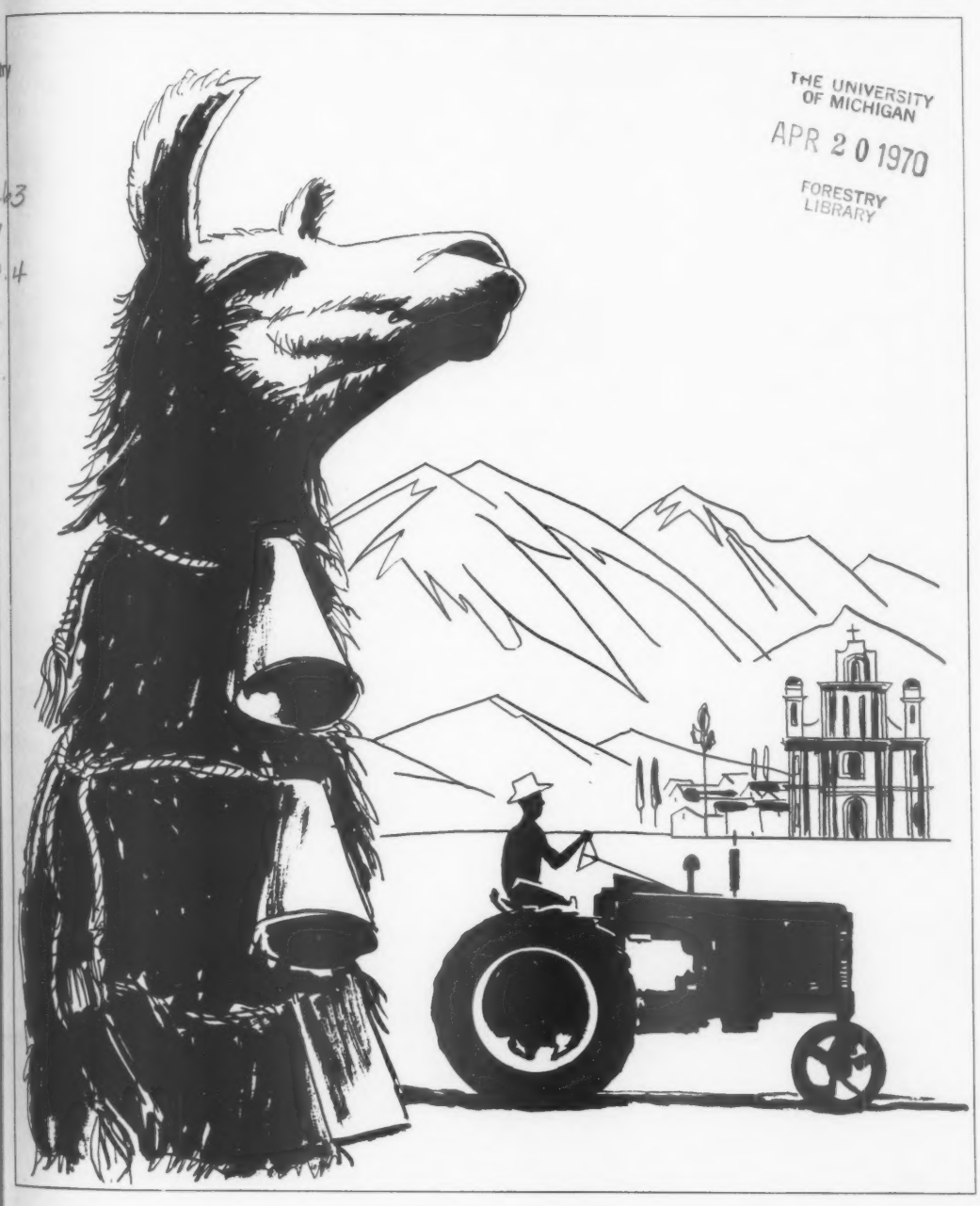

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Agricultural Engineering In Latin America Page 1

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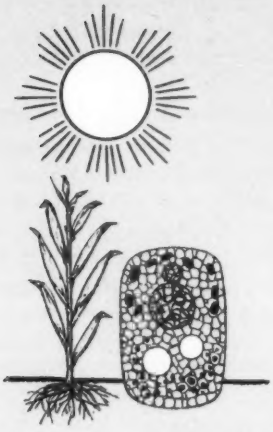

AGRICULTURAL SCIENCE REVIEW
Fourth Quarter 1969 Vol. 7 No. 4

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Trade-Offs in Environmental Issues

A recent bulletin from the Missouri Agricultural Experiment Station has prompted a bit of editorial musing and probing here at the *Review* office. Titled, "The Pesticide Problem—An Annotated Bibliography," it was compiled by J. Charles Headley and Elizabeth Erickson.

Our probing revealed, for instance, that nearly 60 percent of the listed titles appeared in print *before* Rachel Carson's *Silent Spring*—which, incidentally, is included in the bibliography. This fact gives some evidence that scietnists were working on the problem piror to Miss Carson's indictment. Obviously, not all entomologists and plant pathologists of the pre-1962 era could be classified as the "squirt-gun" type.

Further study of the Missouri bulletin showed that some of the cited publications also listed bibliographies. Our tally totaled 2,395 items and we didn't even estimate a count on those that carried the statement, "Includes extensive bibliography."

As anyone knows who has studied the pesticide problem, the literature is indeed vast. Therein lies the merit of the Missouri bulletin. Because it presents only pertinent literature from a wide variety of sources, it seems likely to offer some real help to public policymakers. In other words, the bulletin aims to fill the void that exists between supporters of technology and conservationists.

The senior author, who is an agricultural economist, takes the view that the issues involved have significant economic content and that any rational policy will require a balancing of "trade-offs" in attempting to decide the ultimate quality of our environment.

As the tempo of the issue rises in the public forum, the trade-off idea seems to be gathering more and more proponents. In tropical countries, for example, where pest pressure is more intense than in temperate ones, scientists see little likelihood of a complete ban on certain chemicals. As one speaker at a recent international conference said, it would be better to risk possible liver damage in old age than to die in early youth from lack of protein.—W. W. K.

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AGRICULTURAL ENGINEERING IN LATIN AMERICA

A Conference Report

AT the threshold of the 1970's, Latin America, with its vast human, material and physical resources, faces many problems in its development towards increased food production and improved living standards. Agricultural engineers—alone and in cooperation with others—seek solutions to the involved problems which demand vigorous application of knowledge, initiative, and imagination. Adequacy in preparation of professional personnel demands modern high-quality educational systems in which incomplete or obsolete education cannot be afforded.

As a contribution to the definition of educational requirements for agricultural engineers in Latin America, a Panel on Post-Graduate Agricultural Engineering Education and Research in Latin America was organized and held in Lima, Peru, August 4–8, 1969.

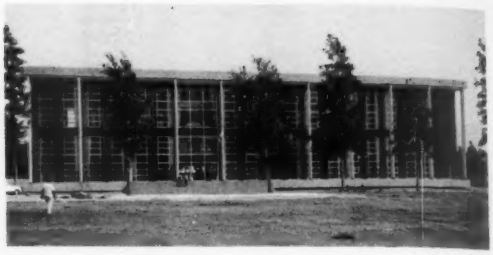
Three agencies sponsored the conference: the Inter-American Institute of Agricultural Sciences, an agency of the Organization of American States; the United Nations, Special Fund for Development; and the National Agrarian University, La Molina, Lima, Peru. The university served as host for the event. When the panel convened, 133 participants representing 20 countries had registered for the full sessions.[1]

Objectives of the conference were: (1) To discuss the role of agricultural engineering in serving Latin American agriculture and its related industries for the advancement of agricultural production and the improvement of rural living; (2) to acquaint participants with the facilities, programs, and activities being conducted at La Molina; and (3) to define both the potential and the requirements for other Latin American institutions considering the establishment of agricultural engineering programs.

The possibility of holding such a meeting had been discussed as early as 1963 by the United Nations Development Program and the Inter-American Institute of Agricultural Sciences. Prior to the conference, there had been little opportunity for an assembly of agricultural engineers to meet and exchange views and ideas on the educational problems of the profession in Latin America. Moreover by

[1] Those from the United States were: Roy Bainer, Calif.; L. L. Boyd, Minn.; J. E. Christiansen, Utah; Carl W. Hall and Howard F. McColly, Mich.; F. J. Hassler and Edward H. Wiser, N.C.; William H. Collins, Wesley Hobbs, and Norman C. Teter—all from the Colombia Mission, University of Nebraska; and Robert G. Yeck, U.S. Department of Agriculture, Beltsville, Md.

Agricultural engineering workshop and laboratories at La Molina.



The library, National Agrarian University, La Molina, Lima, Peru.

1968, only two countries—Peru and Colombia—had initiated graduate programs in agricultural engineering, although other countries were attempting to move toward such programs.

Prior to the 1960's agricultural engineering as a profession had made little headway in Latin America. Students who wished to obtain agricultural engineering degrees had to seek their education in other countries. But when they returned to their native lands, their reception was somewhat less than enthusiastic because the profession was regarded as an encroachment on the traditional fields of agronomy and engineering. However, as the influence of these foreign-trained agricultural engineers began to be felt, attitudes changed.

Two Leading Programs

PERU was the first Latin American country to offer a degree in agricultural engineering. Although a few engineering courses had been offered at the National Agrarian University at La Molina since World War II, actual recognition of the profession did not come until 1959 when the Institute of Agricultural Engineering was formed. In 1960, the institution became the National Agrarian University (UNA) of Peru, and the Faculty of Agricultural Engineering received full academic status by the following year.

In his report to the conference, Professor Jorge Quiroz R., director of the UNA agricultural engineering academic program, cited the phenomenal growth of his department. From an enrollment of 73 students in 1962, the number increased to 565 in 1968—more than in animal husbandry and nearly equal to the enrollment in agronomy. Not only is the agricultural engineering faculty the second largest at the university, but also it maintains a vigorous program of professional improvement. To date, more than 30 faculty members have taken sabbatical leave for advanced study—mostly in the United States.

Research, teaching, and extension are equally emphasized at UNA. The university seeks to apply its intellectual and material values to the national aims of overcoming underdevelopment and improving the welfare of the people of Peru.

Aided by the Inter-American Institute of Agricultural Sciences of OEA and the Special Fund of the United Nations, the National Agrarian University of Peru now offers master degrees in agricultural engineering.

Somewhat similar progress has been made in Colombia. Professor Jorge E. Quintero, director of agricultural engineering of the Colombian Institute of Agriculture, Bogota, reported that professional agricultural engineering at the undergraduate level was started in 1965 at the Agricultural College of the National University in Medellin. Similar programs have since started at other Colombian institutions. Agricultural engineering training in Colombia has been strengthened by the creation of the Institute of Agricultural Sciences (ICA), whose responsibility is to develop, coordinate, and execute work in research, teaching, and extension.

A technical subagency of ICA has the responsibility of organizing, promoting, and directing (a) research to increase agricultural productivity, (b) teaching of agriculture on the vocational, undergraduate, and graduate levels through the cooperation of teaching organizations—especially National University, and (c) the study of agricultural exten-

sion methods and conducting social science research on ways of improving communication methods and practice.

In 1968 an agricultural engineering department was created in ICA on the basis of the national program that had been established. It is located at the National Research Center for Agriculture near Bogota. Its organization and areas of work include soil and water resource development, power and agricultural machinery, engineering of agricultural processes, and rural electrification and structures. For the most part, research has been confined to those problems needing immediate attention—particularly those that concern tropical agriculture. ICA makes a special point of giving training in problems of the region or institution from which the student originates. Engineering students who are deficient in biological sciences are given special remedial courses.

Agricultural engineering programs in other Latin American countries do not lead to a degree, but instead are limited to specified courses in agricultural engineering. Most of them, however, plan to expand and improve their curricula.

Typical Problems

SOME of the factors that contribute to the wide variety of problems awaiting research solution in Latin America were well-delineated by conference participant Norman C. Teter of the ICA-Colombia project, University of Nebraska:

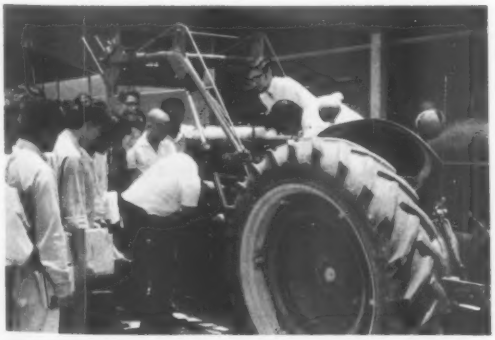
"Latin America includes frigid icecaps, burning deserts, rolling plains, impenetrable forests, mountain heights, and swamps. The people include Caucasians, native Indians, orientals, Negroes from Africa, and every conceivable mixture of these races. The culture is a mixture of tradition-based localism, animism, and a great variety of other 'isms'. It is evident, therefore, that Latin America has a wide variety of problems awaiting research solution. Why, with so variegated an ambience, is Latin America so widely considered as one entity? Would one normally discuss the problems of Nome, Alaska with those of Miami, Fla.?

"Perhaps the common denominator is poverty in the midst of riches—a failure to fully utilize the resources and to achieve the abundant living that we know is possible."

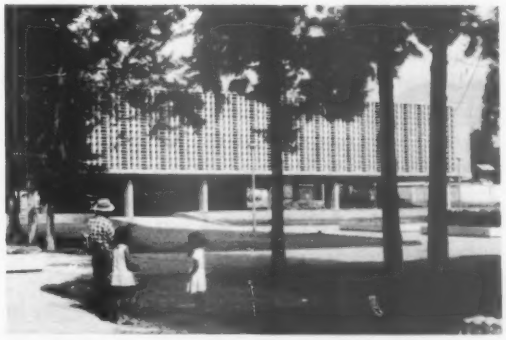
Many of the visiting engineers from other countries emphasized that Latin American agricultural engineering programs should be designed and conducted so as to solve Latin American problems under the conditions that exist in the various geographical regions—and within the available human, physical, and financial resources of each country.

One of the high priority projects, according to Norman Teter and Wesley Hobbs (also of the ICA-Colombia project) is the development of agricultural equipment and machinery manufacturing. Latin American agricultural engineers, they said, can and should play a major role in this endeavor.

"Even if sufficient foreign exchange currency were not a problem—and it is a serious one," the speakers said, "much of the imported equipment is



An agricultural engineering class at La Molina.



Agricultural engineering building, National Agrarian University, La Molina, Lima, Peru.

not suited for tropical and subtropical agriculture. For example, the North American potato planter will not function properly in the tropics where whole potatoes must be planted because of disease problems. Where, for example, can you buy a yuca harvester, or a kikuyo sod cutter? Why, for example, should Colombia purchase farm machinery, except for the highly sophisticated ones such as the large tractors and combines, when it is self-sufficient in steel production, and has the capability to manufacture them?"

Accreditation and Financing

CONCERN was expressed at the conference about the need for Latin-American countries to improve their administrative support and academic standards. Relating experiences of some institutions in the development of an accreditation system, Carlos Garces, Director of Graduate Studies, National University, Bogota, Colombia, stated there was much interest in establishing minimum standards of quality for Latin-American universities.

He traced the growth and improvement of the accreditation system used in the United States and hoped that similar patterns might become prevalent in Latin America. Some progress has already been made in Peru, Ecuador, Colombia, and Venezuela. Greater collaboration and collective interest, he noted, may help to remove some of the egocentrism and isolationism now prevalent.

Clearly, a lack of adequate financial resources is one of the major hindrances to a more rapid expansion of agricultural engineering research and education. Panel members felt that the principal support would have to come from the Latin American governments themselves. However, they recognized that outside fund sources are also needed—particularly where the economy of a country is still in the developing stage. Some outside assistance has already been received—chiefly from the United States Agency for International Development, the International Development Bank, and the United Nations. One panel participant, L. L. Boyd, head of agricultural engineering at the University of Minnesota, pointed out that the most important concept in financing programs is to avoid trying to cover every need but to select the most pressing program areas and concentrating efforts so that a productive, useful job can be done.

Philosophical Angles

DURING the planning stages of the conference, officials felt that the impact and usefulness of the event might be measurably increased by the participation of well-recognized and experienced consultants from abroad. The roster did indeed include such persons, and many of the papers reflected the high quality of the thinking—both from the viewpoints on practical matters and on policy and goals of the profession.

Speaking on the difficulties of implementing effective engineering programs, C. G. E. Downing of the Canadian Department of Agriculture stated that "agricultural engineering must first begin at the grass roots operation and have its impact on agricultural production before there is likely to be any appreciable benefits or improvements in rural living—or, for that matter, in the living standards of the rest of the nation."

"The agricultural engineer," Downing said, "must be a synthesizer of ideas, concepts, and practices and should look at the total involvement of men, machines, and materials in the various agricultural production programs."

Carl W. Hall, head of agricultural engineering at Michigan State University, cautioned against the tendency of minimizing the importance of research in developing countries. Solutions to problems offered by a more advanced economy, he said, might not be applicable because of differences in religious, economical, or sociological environments. He told conference members that "a spirit of improvement and progress will be made by local people if they are involved in improving their economy."

Mindful of the limitations on financial resources in Latin America, Robert G. Yeck, of the U.S. Department of Agriculture, advised researchers from developing countries to scale their planning to the resources available.

"When planning needed research," Yeck said, "many people think of research laboratories and extensive instrumentation for measuring results. Neither may be needed in many of the applied research problems now facing Central and South America." He encouraged field research for most graduate students in the beginning years of a country's program. Moreover, the opportunities to use the resources of other departments, universities, or

governmental and industrial laboratories should not be overlooked.

Dean Emeritus Roy Bainer, College of Engineering, University of California at Davis, sounded a note of optimism when he expressed the belief that the most important engineer of the future will be the agricultural engineer, because food production will be the prime problem. "As a country develops," Bainer explained, "more and more of the problems in agriculture will have engineering implications. Eighty percent of the agricultural problems in the United States are now in this category."

Tour of University Facilities

ONE of the highlights for many conference participants was a guided tour of facilities of the National Agrarian University. Although the new campus has yet to be completed, the buildings, facilities, and grounds stand as an impressive model of what other Latin American countries might well achieve under a program of cooperative effort, dedication to a goal, and benevolent assistance from interested outside agencies.

Campus construction started in 1965 and now totals an area of 26 hectares. Buildings having 42,500 square meters of floor space, in various stages of completion, provide modern and adequate library, laboratory, office, and college union accommodations. The agricultural engineering program utilizes 7,952 square meters of space housing laboratory and faculty facilities for research and study of power and machinery, soil and water, farm structures, and rural planning and farm products processing.

Prior to the tour, H. M. Lapp, local program head of UNDP–80 (United Nations Development Program—Special Fund 80) outlined to conference members the potential of UNDP–80 in serving Latin-American needs in agricultural engineering research and education.

Lapp said it was hoped that students from other countries in the region could utilize the course offerings available at La Molina insofar as accommodations are available. He encouraged other countries to consider sponsoring fellowships so that worthy students could realize their objectives to obtain agricultural engineering degrees.

"As the program develops at La Molina," Lapp commented, "sponsoring agents should think in terms of Latin America and the world." He envisioned agricultural engineering as playing a highly important role in advancing the living standards of the entire Latin American continent.

"A challenge of magnitude has been offered," he concluded. "Cooperation, hard work, and dedication are required to realize success for the worthy objectives of our program here."

Formation of SLAIA

CHIEF highlight of the concluding session of the conference was the initiation of steps to form a Latin American Society of Agricultural Engineers (SLAIA). Professor Quiroz cited benefits that could be derived from such an organization, read a document setting guidelines for a constitution, and then invited discussion. Participants voted unanimously to support the proposal and a pro tem committee was named to prepare a constitution of by-laws embodying the broad objectives for presentation at a subsequent meeting of the newly formed society.

Conference officials expressed the belief that the new society would soon be contributing heavily in advancing and directing the professional development of agricultural engineering in Latin America.

HORMONAL AND ENZYMATIC ACTIVITY OF DDT

JOEL BITMAN

THE strengths of DDT are also its weaknesses. In other words, the problems currently being encountered with DDT are inherent in its advantages.

First, it has a wide spectrum of action and is extremely potent. But this characteristic also poses a problem, since DDT also affects many living things besides insects.

Second, DDT is easy to manufacture and therefore is cheap—about 17 cents a pound. This factor has resulted in widespread and somewhat indiscriminate use.

A third advantage of DDT as an insecticide is its prolonged stability. Its environmental half-life is 15 to 20 years, and a major portion remains in the upper soil layers. This extreme persistence is also one of its hazards. It has been estimated that there is now 1 billion pounds of DDT in the biosphere.[1]

A fourth advantage of DDT is an apparently low mammalian toxicity. Few people or mammals are killed outright by DDT. Yet it is this characteristic that has, in a way, contributed indirectly to the dearth of knowledge about its sublethal effects over a long period of time on man, plants, and animals.

It was this fourth advantage/disadvantage and several associated factors that led the staff of USDA's Pioneering Research Laboratory in Hormone Physiology to initiate research on DDT. Earlier research had shown a marked similarity between the geometry of the DDT molecule and the synthetic estrogen, diethylstilbestrol. This finding in turn prompted investigations of the estrogenic activity of DDT in mammals and birds. But the studies have yielded conflicting results. Because the research of the Hormone Physiology Laboratory has, for some years, involved the biochemical and physiological effects of estrogens, our staff was quite well prepared to determine in detail the estrogenic activity of DDT.

DDT and the Mammalian Uterus

ESTROGENIC activity can be followed by using the uterus as a target tissue for estrogen—the female hormone. The uterus responds by growing; it in-

[1] This figure, proposed by ecologist G. M. Woodwell, is purely an estimate. Presumably it is based on manufacturers' production records during the past two decades and the measurement of DDT stability. Since 1949, the United States alone has produced more than 2 billion pounds of DDT.

creases in weight, in water content, and in carbohydrate, RNA and DNA. By using an immature female rat at 22 days of age, long before any estrogen is produced by the rat, we have sensitive biological tissue with which we can measure estradiol or any estrogenic compound, such as o,p′-DDT.[2]

Previous studies have yielded both positive and negative evidence of estrogenicity. In 1952, Fisher *et al.* (*8*) [3] tested their working hypothesis of an estrogen by using DDT and its analogs, methoxychlor and 2,2-bis (p-hydroxyphenyl), 1,1,1-trichloroethane. DDT and methoxychlor were not able to produce estrus, but the di hydroxy compound did.

The conflicting results continued. In a three-generation test in rats, DDT produced no significant effects upon number of pregnancies, litter weight, or litter number. But during the suckling period, DDT had an adverse effect upon mortality of the young (*18*).

Results in mice were also inconsistent. Deichmann and Keplinger (*6*) found an adverse effect of DDT on several aspects of fertility and reproduction. Another group, however, found that technical DDT produced some trends which were not significantly different from controls (*19*).

A report at the 1968 Federation Meetings by Levin, Welch and Conney (*12*) provided results which offered a possible explanation of the existing differences in the published literature. They found that o,p′-DDT and technical DDT exhibited estrogenic activity in immature female rats while p,p′-DDT showed only weak activity. Since technical DDT contains about 80 percent p,p′-DDT and 15–20 percent o,p′-DDT, the activity of the technical product can be ascribed to the presence of the o,p′-isomer.

On this basis, investigations using pure p,p′-DDT might demonstrate no estrogenic effects while studies with technical DDT might yield other results. And since technical DDT, containing both isomers, is the commercial product which is universally used as the pesticide, an estrogenic action of the ortho-para isomer takes on great significance for mammals, fish, and birds.

The initial work at our laboratory began by comparing the time course of effects of DDT isomers (o,p′-DDT and p,p′-DDT) with 17β-estradiol on several biochemical constituents of the immature rat uterus. Glycogen, an extremely sensitive indicator of estrogen action (*1*), increased after o,p′-DDT administration in a manner very similar to 17β-estradiol (fig. 1), while p,p′-DDT exhibited only slight activity. The o,p′-DDT stimulated characteristic estrogenic responses in the uterus—increases in wet weight, water content, and RNA content 24 hours after administration being similar to those elicited by estradiol.

Using the glycogen response at 18 hours to establish a dose response curve for o,p′-DDT, we found that 6 mg. of o,p′-DDT gave a maximal glycogen response and the minimal effective single dose of o,p′-DDT was 0.4 mg. When we examined the route of administration, we found that the intraperitoneal or oral routes were as effective as subcutaneous injection in rats.

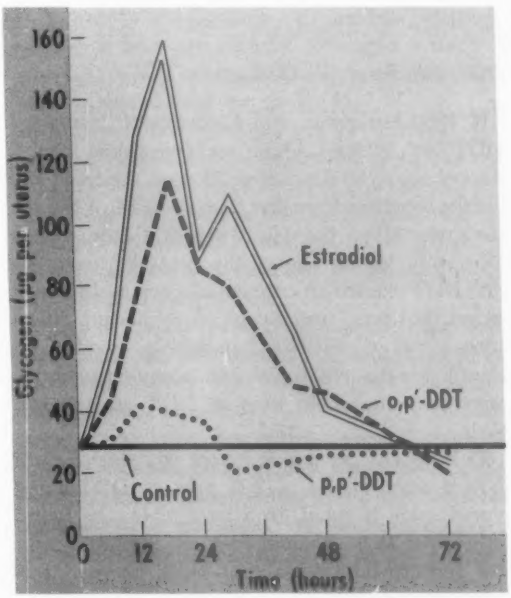


FIGURE 1.—Glycogenic response of immature rat uterus to DDT isomers and 17β-estradiol. Four milligrams of o,p′-DDT or p,p′-DDT, or 0.4 μg of 17β-estradiol, was injected subcutaneously at 0 time. Each point consists of determinations of 4 to 14 uteri of 22- to 25-day-old rats; the control level was established by use of 70 rat uteri. Glycogen was determined by the anthrone procedure.

[2] Abbreviations: p,p′-DDT, 1,1,1-trichloro-2,2, bis(p-chlorophenyl) ethane; o,p′-DDT, 1,1,1-trichloro-2-(o-chlorophenyl)-2-(p-chlorophenyl) ethane; p,p′-DDD, 1,1-dichloro-2,2-bis(p-chlorophenyl)ethane.

[3] Italic numbers in parenthesis refer to Literature Cited, p. 12.

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Our tests showed that MER-25 [4] inhibits the estradiol glycogen response and is almost equally effective in reducing the o,p′-DDT response. The antibiotic actinomycin D has been widely used to inhibit protein synthesis and inhibits the RNA increase which estrogen induces in the uterus. In our tests, the RNA increase which o,p′-DDT induces was also blocked by treatment with actinomycin D.

These results were all obtained by administering a single dose of a rather large amount of o,p′-DDT. The amount of estradiol or diethylstilbestrol which will bring about the same type of estrogenic response is about 10^{-4} of this amount of o,p′-DDT. We were interested in determining what lower level of DDT contamination in the diet, on a continual feeding basis, would be necessary to produce a definite estrogenic effect. Although these experiments are not fully completed, rates of 1,000 ppm and 500 ppm of o,p′-DDT in the diet are estrogenic and cause the vagina of immature rats to open early. In another study, 50 μg of o,p′-DDT per day given to immature rats caused the vagina to open early while p,p′-DDT did not.

DDT and the Avian Oviduct

IN 1950 Burlington and Lindeman (*5*) injected DDT into White Leghorn cockerel chicks from 8 days of age to 89 days. After 25 days, the comb and wattles were much smaller than controls. When the birds were killed, the tests of the DDT-treated birds were only ⅙ the size of the controls, suggesting that DDT exerted an estrogen-like action. In a later report, however, they found no significant differences in red cell numbers, hemoglobin, blood sugar, plasma proteins, plasma calcium, phosphorus, fibrinogen or prothrombin time in DDT and control birds.

DeWitt (*7*) at the Patuxent Wildlife Refuge showed some effects of 200 ppm of DDT upon reproduction in quail. In a later report, he found little effect at a 100-ppm level on egg production and fertility but found that chick survival was reduced. Pheasants appeared to be more sensitive to DDT.

Woodwell (*20*) and Wurster and Wingate (*22*) have determined DDT residues in a number of species of bird and have implicated contamination by insecticides as a probable major cause of the decline in reproduction in several species. In view of the estrogenicity of o,p′-DDT in the uterus of a mammalian species, it was of interest to determine whether sublethal concentrations of this isomer of DDT would have an effect upon the oviduct, the reproductive tract of avian species (*2*).

In experiments with chickens at our laboratory, a single does of o,p′-DDT, even up to 400 mg, would not stimulate the oviduct in 24 hours. Chickens are able to handle a great quantity of o,p′-DDT if given subcutaneously or orally. But if given by intraperitoneal injection and given repeatedly, the oviduct will respond to the o,p′ isomer. Three daily doses of 50 mg of o,p′-DDT doubled oviduct weight—from 65 to 122 mg—and more than doubled glycogen content. p,p′-DDT had no effect. Experiments with Japanese quail produced a very similar effect; o,p′-DDT doubled oviduct weight and tripled oviducal glycogen.

One possible hypothesis for an action of o,p′-DDT, in contrast to p,p′, is that the o,p′ isomer might accumulate to a greater extent and exert an estrogenic action because of this preferential uptake. We examined this possibility by determining the pesticide content of rat, chicken, and quail tissues after 4 days of pesticide treatment. In rats, o,p′-DDT was found to accumulate to a much lesser extent than p,p′-DDT, by a factor of 5 to 8.

In chickens and quail, the accumulation of o,p′-DDT was similar to the p,p′ accumulation, indicating that no selective accumulation took place. It was concluded that the estrogenic activity of o,p′-DDT was associated with the o,p′-DDT molecule or a metabolite or impurity rather than any preferential uptake of the compound as compared to p,p′-DDT.

Structure Activity Relationships

SINCE the physio-chemical basis for estrogenic activity is still not known, we became interested in learning whether the estrogenic activity of the o,p′-isomer has important implications for the mechanism of estrogen action. The exact nature of the active estrogen structure arising from o,p′-DDT—if it is not o,p′-DDT itself—might provide important theoretical information about the spatial configuration of an active estrogen. Schueler (*17*) had proposed that a large, rigid molecule with the same

[4] MER-25 is 1-(p-2-diethylaminoethoxyphenyl)-1-phenyl-2-p-methoxyphenyl ethanol.

spatial characteristics as diethylstilbestrol would be estrogenic. Although p,p′-DDT comes fairly close to the proper measurements, o,p′-DDT is much too short.

This problem was approached in a largely empirical way. By having a similar spatial or molecular configuration, DDT or an analogue might occupy receptors in reproductive organs and tissues and thereby exert direct estrogen action. We used the 18-hour glycogen response in the imature rat and determined the presence or lack of estrogenic activity in a series of DDT analogs and in a series of structurally related compounds, which had halogen or other substituted atoms. The information gleaned from this study may provide a link to the nature of the chemical structure that induces estrogenic response.

About 50 compounds have already been tested. Nine of these compounds have been positive; all are diphenylmethane compounds and are not dibenzyl or stilbene structures. All were active at a 4-mg dose; several of them seemed to be active at much lower concentrations. This research will continue.

The Thin-Eggshell Theory

MUCH has been written about the effects of DDT on wild bird species. Declines in populations of some species have been linked to increased levels of DDT and other pesticides in the environment. The problem here, however, is whether the relationship is a causal one or a casual one, which statistically would be a nonsense correlation.

That some birds species have declined since the introduction of DDT is, of course, a documented fact—although it is known that similar declines have occurred among both avian and mammalian species long before the use of pesticides. Presently, decreases are occurring mainly in predatory birds that eat fish or small mammals: bald eagles, osprey, peregrine falcons, sparrow hawks, kestrels, herring gulls, and Bermuda petrel. The decline in these bird populations is assumed to be due to greater shell breakage, because of eggs with thinner shells.

The basis for the thin-eggshell theory originated primarily in two studies. In 1967 Ratcliffe (*15*) examined blown eggs of 3 British species—the peregrine falcon, sparrowhawk and the golden eagle—which had been collected from 1900 to 1966. He plotted time versus an index of eggshell thickness. He noted a decrease in eggshell weight, which he contended was correlated to exposure of the eggs to persistent organic chemicals. Ratcliffe based his conclusion solely on the fact that pesticides were becoming more prevalent in the environment.

In 1968 Hickey and Anderson (*9*) examined eggshell weight and thickness in 1,729 blown eggs that had been collected from 1880 to 1967. These eggs were in museums and private collections, and in 30 percent of the eggs they were able to insert a micrometer to measure shell thickness directly. They found a decrease of 19 percent in peregrine falcon shell weight in the 1947–52 period. Hickey and Anderson also collected eggs from 5 herring gull colonies in 5 different states and analyzed the eggs for DDE and measured the shell thickness. They found a high correlation between DDE content and thinner eggshells.

Thus, from these two studies, came the hypothesis that eggshell thickness is affected by certain chlorinated hydrocarbons.

Acting on the decision that such a hypothesis needed to be tested directly, we began a study in which o,p′-DDT and p,p′-DDT were incorporated into the diet of Japanese quail (*3*).

Birds were divided into 3 groups—controls, o,p′- and p,p′-DDT. Birds in the control group received *ad libitum* a chick starter diet of low calcium content, which provided a calcium stress during egg laying. The o,p′-DDT and p,p′-DDT groups received the same diet modified by the addition of 100 p.p.m. of the pesticide.

Eggs were collected daily for a 45-day experimental period and the presence of broken eggs was recorded. During this period, 1,020 eggs were collected.

Egg production, egg weight, eggshell thickness, eggshell calcium, bone calcium, blood calcium, bird weight, and pesticide residues in the eggs, liver, and lipid—all were measured. We determined calcium by atomic absorption analysis after wet ashing of eggshells and bone. Pesticide residues were determined by gas chromatography. Eggshell thickness was measured at 3 places at the waist of each egg with a micrometer, after removing the shell membranes. The beta backscatter method of James and Retzer (*10*) was used to study the relationship between eggshell thickness and backscatter.

The o,p′- and p,p′-DDT diets produced a lag in egg production during the 1st half of the experiment (fig. 2). During the last half of the experiment there was little difference in numbers of eggs produced. This lag suggested a lag in ovulation in these groups and a delay in ovulation produced by p,p′-DDT has been reported by Jefferies in the Bengalese finch (*11*). Eggs produced by birds on the p,p′-DDT diet were significantly smaller than those produced on either the o,p′ or control diet.

The p,p′-DDT diet produced a great number of broken eggs—15.6 percent as compared to 11.1 percent in the control group. Individual egg-laying records of the birds showed that most of the broken eggs were coming from a few birds. The quail responsible for producing most of the broken eggs were classified as susceptible. In the control group only 3 birds were susceptible, but the o,p′- and p,p′-groups had 5 and 6 birds producing broken eggs.

Eggs from the o,p′ and p,p′ groups were significantly lower in percent of shell calcium and had thinner shells than eggs in the control group. In these experiments broken eggs which fell through the screen floors to the pans below the cages were not recovered. It is very likely that these broken eggs would have had thinner shells and lower calcium contents. Accordingly, there is a bias in the data, and the decreases observed would probably have been greater if all eggs had been recovered and measured.

Individual egg-laying records also showed what was happening as successive eggs were laid in a clutch. Typically, quail and chickens lay an egg 1 day, another on the next day, another on the third day, another on the 4th day, and so on. Then there may be a break of a day or two and egg laying resumes. The group of eggs laid successively is called a clutch, and can consist of a 2-egg clutch, 3-egg clutch, 4-egg clutch, and so on. Egg-laying records showed a decrease in thickness and in percent shell calcium in the o,p′- and p,p,′-DDT groups as successive eggs were laid, and only a slight decrease in control eggs. At the end of a clutch, during the nonlaying interval, the bird restores the drain on the calcium balance and the first egg of the next clutch has a higher shell-calcium content and a thicker shell. Pooling of all data tends to mask this effect and calculation of group means reflects only part of the calcium decline.

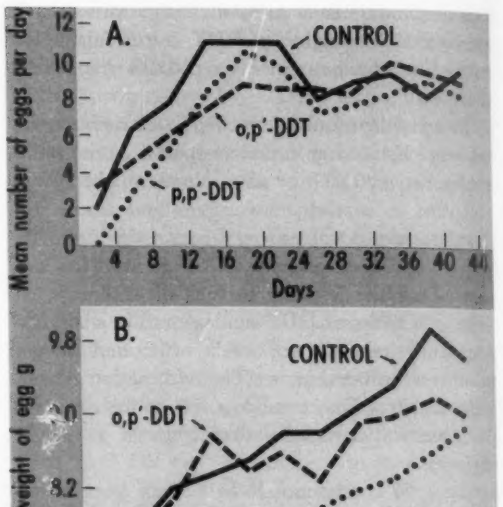

FIGURE 2.—Effect of DDT on egg production (top half of chart) and egg weight (lower half).

Regression lines for the o,p′- and p,p-DDT groups were significantly different from the control regression lines and exhibited 10 to 20 percent decreases in percent shell calcium as clutch size increased. Also, eggshell thickness decreased as clutch size increased.

Blood calcium concentrations were determined on the birds at the end of the experiment. No significant differences in the three groups were noted.

Although o,p′- and p,p′-DDT were fed at the same rate, approximately 20 times more p,p′ was accumulated than o,p′. The liver of the p,p′-group had 1,400 p.p.m. compared to only 56 p.p.m. of o,p′ in the o,p′-group. These results suggest a much greater metabolism and excretion of o,p′-DDT than p,p′. In spite of the relatively low body or egg burden of o,p′-DDT compared to p,p′-DDT, the two compounds were equally effective in reducing eggshell thickness. This suggests that toxicological effects are more closely related to intake than to body or egg burden.

Relatively low amounts of p,p′-DDE were found in the bird tissues and eggs. Only about 10 percent of the total pesticide residue was p,p′-DDE. Several bird investigators have reported that p,p′-DDE usually makes up 80–90 percent of the total pesticide residues found in environmentally collected avian samples. The explanation for this difference probably lies in three factors: (1) our relatively short-term experiment; (2) immediate workup and (3) no prior conversion of DDT to DDE by the environment.

The experiment we conducted confirms in a direct way the previously reported correlative evidence of Ratcliffe and Hickey and Anderson that DDT induces a decrease in eggshell calcium. Although the dietary levels used in our experiments were high and seed-eating birds would probably never encounter DDT concentrations of this magnitude, there is evidence in the literature that carnivorous birds have been exposed to extremely high DDT concentrations. Riseborough (*16*) had reported total DDT accumulation levels of 5,000 and 2,600 ppm in the lipid of North American falcons—considerably above the 1,500 ppm in our study. These higher residue levels suggest that predatory birds in the field are exposed to body burdens of DDT which could readily exert the adverse effects upon calcium metabolism and eggshell thickness which we demonstrated in the laboratory.

Mechanism of DDT Action

THE mechanism by which DDT exerts its effect upon eggshell calcium is one of the most interesting problems of the DDT picture. Several possible modes of action have been suggested.

1. Stimulation of liver enzymes which degrade steroids necessary for calcification resulting in an upset in hormonal balance.
2. Inhibition of medullary bone deposition—the primary source of calcium during eggshell formation.
3. Inhibition of the parathyroid gland.
4. Inhibition of the thyroid gland.
5. Inhibition of calcium absorption from the gut.
6. Inhibition of carbonic anhydrase activity in the avian shell-forming gland.
7. Abnormal stimulation of the nervous system resulting in premature extrusion of the egg.

Not much has been published about these possible modes of action, but apparently the liver microsomal enzyme theory is the favored one at present. Peakall (*14*) used pigeons treated with p,p′-DDT and found that the liver microsomes formed greater amounts of polar metabolites from estradiol, testosterone, and progesterone than microsomes from untreated birds. A direct link between this finding and the calcification process has not yet been reported.

One of the approaches our laboratory has been using to determine the effect of DDT upon the liver is to measure sleeping times. The rationale for this method is the fact that essentially only the liver metabolizes barbiturates. A given dose of barbiturate will put an animal to sleep for a certain length of time. Liver metabolism eventually removes the anesthetic from the system. If liver enzymes are stimulated, the dose of barbiturate will be metabolized in a shorter period of time and the animal will be asleep for a shorter period. Conversely, if the liver enzymes are inhibited, it would take a longer time to handle this dose of barbiturate and the animal would stay asleep longer.

Because organochlorine insecticides such as DDT stimulate liver enzymes in the rat, sleeping times of DDT-treated rats are shorter than those of controls. The o,p′ and p,p′ isomers of DDT, DDD, and DDE were fed to immature and mature rats to determine the time course of their effect upon sleeping time. p,p′-DDT reduced sleeping time to 50 percent of control after 2 days and to 5 percent of control at 7 days. There was little further reduction at 14 days. p,p′-DDT had less effect in mature rats, reducing sleeping time to 75, 40, and 40 percent at 2, 7, and 14 days, respectively. Body lipid residues of o,p′-DDT were only about 1/10 those of p,p′-DDT.

In contrast to the shortening of sleeping time observed in rats, the DDT isomers and metabolites prolonged sleeping time in Japanese quail (*4*). p,p′-DDT produced the greatest prolongation of sleeping time—to over 300 percent of controls. In quail lipid, p,p′-DDE and p,p′-DDT increased linearly with increasing time on the diet. Prolongation of sleeping time, however, was not maintained although p,p′-DDE and p,p′-DDT lipid residues increased, which suggested an adaptation to this stimulus. All o,p′ compounds and p,p′-DDD were metabolized rapidly and exhibited very low accumulations in quail lipid.

The prolongation of sleeping time in the quail suggests that the liver microsomal enzymes which metabolize pentobarbital were inhibited by prior DDT treatment. The data that Peakall has reported in the pigeon indicate that the liver microsomal enzyme system which metabolizes steroids was stimulated. Although these systems usually go together, there is a dissociation of effects here.

Future Research on DDT

THE persistence of the organochlorine compounds, especially DDT, in the environment insures their presence in biological systems for many decades even if future use is further limited by legal or scientific considerations. DDT, DDD and DDE presently account for over 50 percent of the total chemical residues present in human food. The nature of the biological effects which DDT and its metabolites produce in farm animals, birds, and man are thus problems of significant biological importance and merit continued study.

There have been a number of previous studies of the gross effects of large and near lethal amounts of DDT (*13*) and an extensive literature exists of a survey nature detailing the organochlorine content of animals, animal products and plant materials. It seems fair to state, however, that our information on the mechanism of action of DDT and on subtle low-level effects is still meager. This has now become a focal point of widespread concern. Since we must continue to live with these residues for some time to come, we would do well to learn as much as we can about them.

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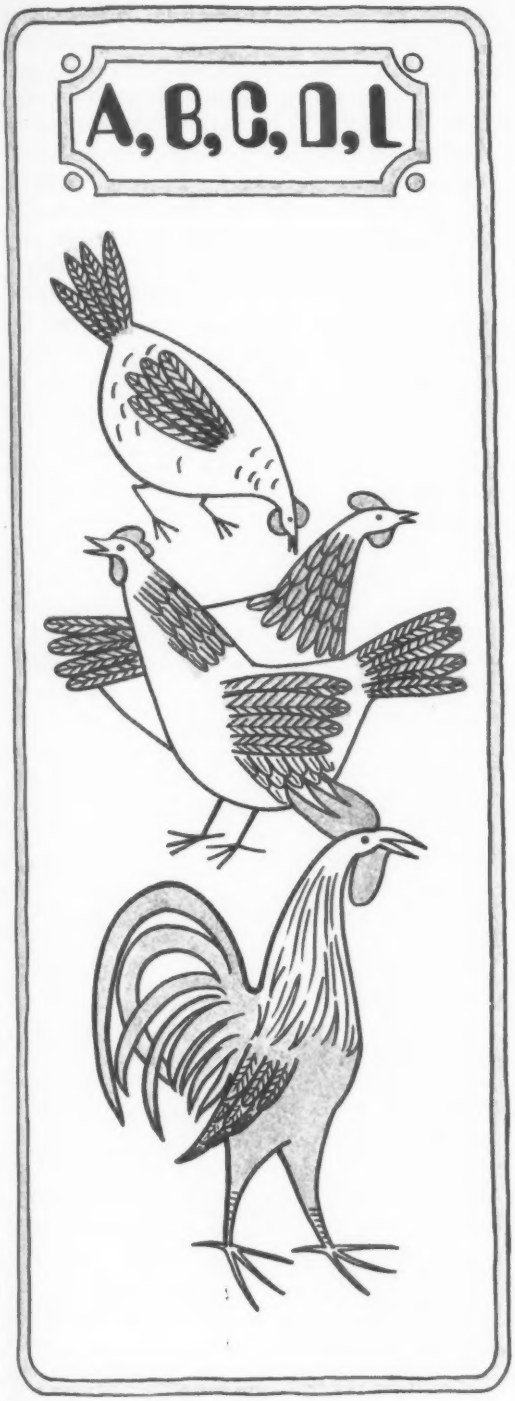

BLOOD GROUP RESEARCH IN CHICKENS

DOUGLAS G. GILMOUR

A LITTLE over 10 years ago, interest in the blood group of chickens was at its crest. Research laboratories had been setup, or were being setup, by companies involved in poultry breeding and by government agencies, State experiment stations, and universities interested in agricultural matters. The earliest research activity occurred in the United States and England, but quite a number of other countries joined in later. Although a few institutions were mainly concerned with the basic aspects of this subject, the major impetus for this expansion of research was the hope that blood groups would become an important aid in the rapid genetic improvement of poultry.

It is fair to say that this hope has not been realized. Although some limited use has been made of blood groups in the further improvement of already very good stock, they are as yet of little general use in stock improvement at any level. On the other hand, some ways have been suggested in which blood groups may aid in solving problems of parentage, misidentification, and mispedigreeing, and these uses may be of value to breeders.

From a basic research viewpoint, the situation is much more promising. Important advances in understanding the genetics of natural populations and

evolutionary biology are now emerging from chicken blood-group studies. In addition, chickens of known blood group are being increasingly used in research on basic immunology, cancer, transplantation biology, and the effects of radiation.

Widespread interest in chicken blood groups arose when it was realized that they were characteristics which: (1) were accurately identifiable (with suitable technical expertise); (2) developed from the action of specific single genes, without modification by environmental factors; and (3) exhibited considerable genetic variability between individuals within breeds or strains. They promised something the breeder could get to grips with, and thus were refreshingly different from the supposed genes which affected economically important traits such as egg production, growth rate, fertility, and hatchability.

The existence of these latter genes could be inferred only indirectly. There were probably many of them, and their effects on production traits were only too modifiable by environment. Other single-gene characteristics which were clearly identifiable, such as comb shape, color of feather, down or skin, were usually fixed within breeds and strains, and thus were of limited interest to breeders.

The blood-group genes came to be thought of by some breeders and research workers as marker genes, which might show association with production traits, and might thus serve as aids for the easier identification of genetically superior individuals or families. The nature of the associations that have since been found has made their application in breeding a difficult and generally not worthwhile proposition. I believe that much of the rush to apply blood groups to practical problems was premature. It was first necessary to gain, from basic research, a broad understanding of their place in the natural order of living things. Perhaps the time is not far distant when enough basic knowledge will have accumulated to allow a fresh appraisal of the possibilities for application, but not yet.

Properties of Blood Groups

BLOOD groups have been extensively investigated in a number of animal species, such as cattle, sheep, swine, chickens, and man. Their characteristics are determined by chemical structures on the surface of the erythrocytes (red blood cells) known as blood-group factors or antigens. Antigens have two important properties: (1) when transferred into other individuals or animals they stimulate formation of specific antibodies; and (2) they are reacted upon by these antibodies, in the body or test-tube, so that the cells are either agglutinated (clumped together) or hemolysed (dissolved). In these properties, blood-group antigens are similar to antigens of infective organisms such as bacteria, viruses, and protozoan or worm parasites. These antigens also stimulate the formation of specific antibodies, whether during an infection or an immunization, which are then capable of clumping or dissolving the organisms.

Immunological responsiveness probably developed in evolution as a protection against attacks by invading foreign cells. Such cells include infective organisms as well as tumor cells derived from the host's own cells by malignant transformation, but not, usually, the red blood cells. The development of blood transfusion in clinical medicine led to the discovery that antibody reactions could occur against red blood cells, and hence to the realization that the possession of specific antigens is a general property of living cells, and is not just restricted to invasive cells. More recently it has been found that red blood cells do sometimes invade other organisms without medical intervention. In some cases small amounts of a baby's blood can enter the mother's circulatory system across the placenta, and can stimulate antibody formation. Such antibodies may harm babies in later pregnancies, leading to hemolytic disease of the newborn (Rh disease). Antibodies originating in this way are of great value in research on new blood-group systems in man (*22*).[1]

The term "blood group" was originally used in connection with the first blood-group system known in man—the ABO system. There were only two characteristic antigens involved—A and B. Individuals could be grouped into one of four categories, A, B, AB or O, according to whether they possessed either antigen A or antigen B, or both or neither. Thus, the term "blood group" referred to a group of individuals possessing the same antigen or antigens. In transfusion centers people are usually also grouped for a second system—Rh—and are classed either Rh positive or negative. Thus eight common groups are probably familiar to most of us.

[1] Italic numbers in parentheses refer to Literature Cited, p. 21.

With the large numbers of other systems and antigens now known in man, classification into unique groups is no longer feasible, and instead it is stated merely whether an individual possesses or lacks particular antigens. The same situation applies in animals. The term "blood group" has thus acquired a meaning in addition to its original one. It is now used, particularly in the adjectival form, as generally descriptive of inherited antigenic properties of erythrocytes, as: blood-group antigen, blood-group system, blood-group gene, etc.

Identification of Blood-Group Antigens

BLOOD-GROUP antigens are studied by means of either agglutination or hemolytic reactions with specific antibodies. Some animals such as cattle and sheep, but not chickens, possess a blood-group system analogous with human ABO, in which the specific antibodies occur naturally without prior immunization and are normally present in the blood serum. Their occurrence is reciprocally related to the presence of the antigens; for example, individuals possessing antigen A have anti-B antibody in their serum but not anti-A. These antibodies are used directly as identification reagents for red blood cells possessing the particular antigens. All other blood-group systems of man and animals are studied with other types of antibodies, either those normally present in the sera of other species, or, more commonly, immune antibodies: that is, those produced as a result of immunization with red cell antigens.

In making immunizations for the purpose of manufacturing blood-group reagents, red blood cells may be introduced into members of another species (hetero-immunization) or into members of the same species (iso-immunization). The latter is preferred since iso-immune sera usually have greater power to discriminate fine genetic differences. This power probably arises because iso-immune sera contain only antibodies which distinguish individuals within the species, whereas hetero-immune sera also contain very powerful antibodies which distinguish one species from another. This difference follows from the fact that an individual cannot produce antibody against an antigen which he himself possesses. Thus, immunization between a pair of individuals of the same species can produce antibodies against only those antigens which the donor possesses and the recipient lacks, and not against antigens which all members of the species have in common.

Because of the great variety of blood-group antigens present in most animal species, a single iso-immune serum often contains several specific antibodies. These may be sorted out by absorption analysis, which makes use of the fact that when cells carrying a particular antigen react with specific antibody, they combine with that antibody and remove it from solution; that is, they absorb it. The importance of absorption as a research tool in this field was established as long ago as 1910 in two classical papers by Todd and White (*24*). They investigated the red blood cell antigens of cattle using absorptions of iso-immune sera, and obtained the first evidence in any animal that there was a multiplicity of antigenic differences between individuals, and that these differences were inherited.

Todd's Historic Studies

TWENTY years later, Todd (*23*) carried out a similar study with chickens. In order to prepare an anti-fowl-plague serum, he had injected numerous chickens with infected whole blood from other chickens, and found that powerful iso-agglutinins for red blood cells were formed. Each individual serum agglutinated some but not all cells, and those cells which were agglutinated differed with each serum. Moreover, the same blood injected into different individuals produced sera of differing reactivity patterns.

Reasoning from these findings, Todd concluded that pooling a number of immune sera would produce a highly polyvalent serum which would react with almost all types of cells. Furthermore, if such a serum were absorbed with cells of any individual it would still react with almost all other cells and would act as a highly specific negative reagent for this individual and for others identical with it. Such was the case. Portions of a pool of sera from numerous immunized chickens were absorbed separately with cells from each of 90 other chickens, and then tested against cells of all 90. In every case, when the serum was sufficiently absorbed so that it did not agglutinate fresh cells from the individual who had provided the cells for absorption, it still agglutinated cells of all the other 89 fowls tested.

In later family studies, Todd found that the polyvalent serum absorbed with blood of one parent of

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a family of chicks failed to agglutinate cells of 20 to 30 percent of the offspring, but when absorbed with blood of both parents invariably failed to agglutinate cells of all offspring. His main conclusion was that the red cells of chickens possess a great multiplicity of antigenic affinities which are inherited as dominants (strictly, co-dominants: that is, no recessivity). This conclusion has been confirmed by later detailed research on the separate blood-group systems of chickens.

Application to Disputed Parentage and Mispedigreeing

TODD's methods may be directly applied to practical poultry breeding in two ways. The first is suitable for relatively non-inbred stock, where no two individuals are likely to have the same pattern of red cell antigens. A highly polyvalent serum will then be rendered non-reactive for an individual's red cells only when absorbed with cells of both parents. This fact provides a basis for determining parentage on one side—usually the sire—when the other parent is known.

The feasibility of such a method was tested by Mitsumoto and Yamada (*19*). Individual hens were artificially inseminated with mixed semen from pairs of cocks carrying contrasting marker genes for feathering or coloring, so that the progeny could be accurately assigned to sire. A polyvalent serum absorbed with red cells of the dam and one sire invariably failed to agglutinate red cells of his true progeny, but always agglutinated red cells of the progeny of the other sire by the same dam. In further trials with carefully pedigreed matings, it was demonstrated that sharp discrimination was possible even between sires of the same breed.

This method can be particularly useful whenever males are changed in single-male breeding pens, as when dams are used sequentially in both pure and cross matings. No time need be wasted in holding back eggs while waiting to ensure certain changeover of siring. Even greater benefit will be obtained in breeding systems based on testing complete diallel crosses of several strains. Here, the maximum genetic information is obtained when each dam group is crossed successively with sires from all strains. By eliminating waiting periods between shifts, such programs can be completed in a reasonably short breeding season.

The other main application of Todd's methods is suitable for relatively inbred stock where antigenic differences between members of one line are likely to be much less than those between members of different lines. Polley and Craig (*21*) tested the possibility of using this principle to discriminate between different inbred lines. Fifty-six noninbred chickens were immunized singly with red cells from 56 individual donors from 5 inbred lines. A separate reagent for each line in turn was made as follows: All the sera made against red cells of individuals of the other four lines were pooled so as to give a highly polyvalent serum. This serum had somewhat lower agglutinating activity against red cells of the one line than against those of the other four. It was then absorbed with washed red cells pooled from numerous individuals of the one line until it had no reactivity against cells of any individual of that line. At this stage the serum still agglutinated cells of any individual from the other four lines. Thus it was a suitable "identity reagent" which served to distinguish one line from the other four.

Some large-scale breeders of incross hybrid chicks now use reagents made along similar lines as a means of checking the genetic purity of grandparental and parental stocks—both on the breeders' own farms and, more importantly, on the farms of franchised multipliers. The detection and eradication of interlopers in such flocks depends on their positive reaction in a simple and rapid field test with the appropriate identity reagent.

Genetics of Chicken Blood Groups

THE detailed genetics of chicken blood groups has been studied by Briles and his coworkers, and to a lesser extent by myself. The methods used were based on the principles outlined above, and have been reviewed in detail (*3, 11, 18*).

At least 11 separately inherited blood-group systems are known in the chicken, each of which is determined by a separate genetic locus (*4, 11*). A locus is defined as a site or position on a chromosome where two or more alternative genes (alleles) occur. These systems, and the corresponding genetic loci, fall roughly into two levels of serological and genetical complexity.

At the simpler level very few alleles occur at a locus, often only two, and these determine the in-

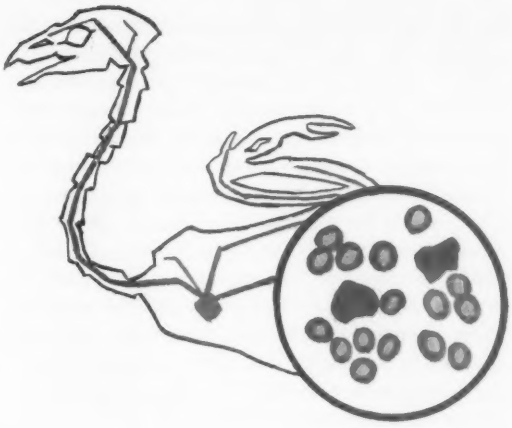
heritance of the same number of simple antigens. Eight systems in the chicken are of this type, each known by a separate letter—D, H, I, J, K, L, N, or P. Typically the two antigens, say L_1 and L_2, are determined by allelic genes L^1 and L^2 at a genetic locus L, and are identified by reagents (monospecific antibodies) L^1 and L^2. The genes carried by an individual make up its genotype; thus an individual with antigens L_1 and L_2 has the genotype L^1/L^2. Six of these 8 simple systems have not yet been found outside the inbred lines in which they were first detected. But two, D and L, have now been identified by several investigators other than their discoverers.

At the complex level are three other systems in the chicken, A, B, and C. Each locus has many alternative genes (multiple alleles)—probably a dozen or so in *A* and *C*, and several hundred in *B*. Each allele determines the formation of an antigen which, although inherited as a unit, is complex in structure. For the B system, this antigenic complexity is demonstrated by the following observations (*6, 10*):

If a reagent is made by immunizations between inbred birds, it appears monospecific for the antigen against which it was made, but only when used for testing birds of the original line. When such reagents are tested against cells of birds of other lines they show a variety of different patterns of overlapping reactivity, usually called cross-reactivity. Each complex antigen may thus be thought of as made up of an assortment of sub-antigens or antigenic factors, some of which are the same as, and others different from, the factors making up other complex antigens. In contrast, the antigens of the simple systems rarely exhibit cross-reactivity and are probably not complex in structure. Accordingly, reagents made in one line are usually just as specific when used in any other line. For example, the original L1 and L2 reagents were successfully used to identify the antigens L_1 and L_2 in a number of other lines and populations (*13*).

Genetic Polymorphism

THE blood-group loci, whether in chickens, other animals, or man, represent examples of balanced genetic polymorphism. This is a situation in which two or more distinct identifiable genetic types exist



together in a population. By definition, the frequency of the rarest gene at a polymorphic locus must be greater than that which could be maintained by recurrent mutation alone. A frequency of greater than 1 percent is generally accepted as meeting this criterion. At least five chicken blood-group loci (A, B, C, D, L) have been shown to be polymorphic in many populations.

Polymorphism is more widespread at the loci with more alleles, hence more at *B* than at *A* or *C*, and more at these than at *D* or *L*. The occurrence of these polymorphisms provides the theoretical grounds for supposing that associations of blood groups with production traits will be found, for it is known that polymorphisms develop and are maintained by natural selection, epitomized as the "survival of the fittest." Fitness in this sense involves both viability and ability to reproduce, and thus includes most traits valuable to the poultry industry.

The earliest theorizing on the causes of the polymorphism of blood groups involved the genetic locus controlling the four major human blood groups O, A, B, and AB. It was known that these four groups occurred at specific but widely differing frequencies in various well-defined human populations, and that within each population the frequencies showed remarkable stability over long periods of time. Most scientists in the 1930's therefore supposed that the genes controlling these blood groups were neutral in selective value.

Fisher (*8*) had already shown, however, that exact neutrality of any gene was highly unlikely, and that stability of gene frequencies was impossible in

the presence of even very minute differences in selective value of alleles. Consequently, Ford (*9*) treated human blood groups as examples of balanced polymorphism, in which stability was maintained by a balance of selective advantage and disadvantage attached to each allele. Because of the evolution of dominance (*7*), the advantageous effects would become dominant and the disadvantageous recessive. A heterozygous individual, having both alleles, would then exhibit the dominant advantage of each but the recessive disdavantage of neither. On the other hand, a homozygous individual, having a pair of like alleles, would exhibit both the advantage and disadvantage of that allele, and would be inferior to the heterozygote.

Association with Production Traits: Inbreds

THE first evidence of an association between chicken blood groups and economic characters was indirect, and emerged from the response of blood groups to inbreeding. We expect genetic variation within lines to be very much reduced by inbreeding, because genetically alike individuals are bred together. Up to a point, this expectation is realized with the blood groups. The numerous multiple alleles of the A, B, or C systems, which are usually found in outbred populations, are quickly reduced in numbers at low levels of inbreeding. According to theory, this process should continue with further inbreeding to the stage where the loci become fixed; that is, represented by only one allele, so that all individuals in the population are homozygous.

With blood groups, however, this stage is not reached, or is at least considerably delayed. When only two alleles are left, they usually continue segregating during long periods of inbreeding (*6, 10, 11*). This provides a powerful indirect argument that differences in survival value (reproductive fitness, viability, or both) are associated with the blood-group genotypes. Specifically, the heterozygote must be superior to its corresponding homozygotes, for if the genotypes survived equally, the process of inbreeding would inevitably lead to loss of the heterozygote. Direct evidence was subsequently obtained that, within inbred lines, blood-group heterozygotes did indeed survive better than homozygotes (*5, 11*).

The above evidence supported the view that blood-group polymorphism is maintianed by heterozygote superiority, but was obtained only in an inbreeding situation. It is thus not necessarily relevant to the basic question of the existence of blood-group polymorphisms in outbred populations. On the practical level, moreover, there could be little interest in these findings. Inbred lines are usually developed by breeders as sources of uniform and prepotent (hence homozygous) parents or grandparents of hybrids; thus, the superior survival of heterozygotes among inbreds was irrelevant.

Advances in Theory of Polymorphism

IT has become clear that Ford's original proposition was an over-simplification. Each polymorphism of two alleles represents a drawback to the population as a whole, since the selective disadvantage of the homozygotes lowers average population fitness. No population could support more than a few such polymorphisms and hope to survive. Nevertheless, whenever a natural population of animals or man is studied, many loci are found to be polymorphic. My colleagues and I have attempted some theorizing (*12, 14, 20*) to explain this dilemma. We proposed that stable polymorphisms are divided into two major types, not necessarily mutually exclusive, involving either rather few loci with multiple alleles; or many, usually diallelic, loci with considerable interaction between them.

With multiple alleles, as at the *A*, *B*, and *C* blood-group loci, polymorphism will be maintained by a general heterozygote advantage, but without much lowering of population fitness since the frequency of deleterious homozygotes is low. The latter follows because, on average each gene will occur much more often in a heterozygous combination than in a homozygote. For this situation, Mandel (*17*) showed theoretically that an important additional factor in the maintenance of polymorphism would be the existence of stable differences in the fitness of various heterozygotes. Since any outbred population is largely composed of heterozygotes, these differences would be the important ones to investigate, for both basic and practical reasons.

The second type of polymorphism we proposed involved many diallelic loci. These might be the "simple" blood-group loci, as well as loci controlling various polymorphic enzymes and proteins of tissues, blood serum, and egg white (e.g., 2). In these cases adequate population fitness would be

maintained only if the heterozygote advantage in fitness at each locus were extremely small, but then the number of polymorphisms would very likely be reduced by random fixation. This would be avoided if interactions between loci occurred, of such a nature that only certain multiple homozygotes were extremely deleterious. We suggested that interactions should be investigated, and might be more readily detectable than the small degree of overdominance per locus.

Associations with Production Traits: Outbreds

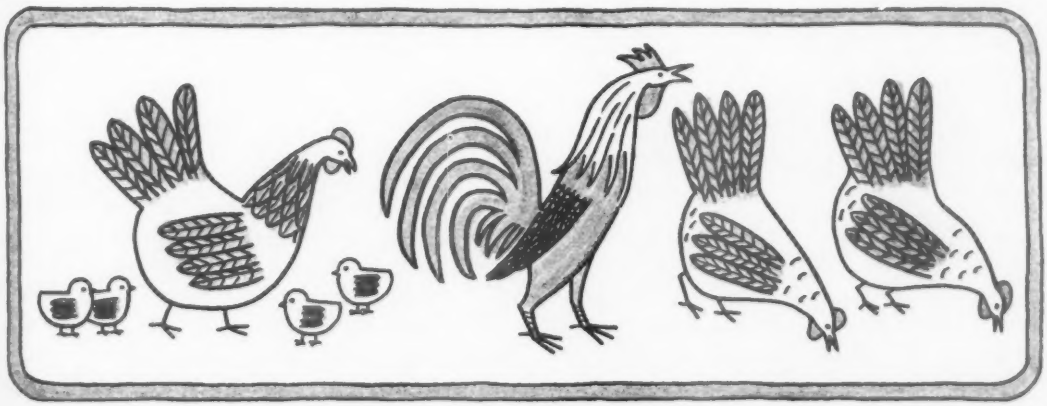
As a test of our theoretical predictions, we have investigated the association of both types of polymorphism with hatchability in a large commercial flock of Light Sussex chickens (*14, 15, 20*). This flock, although slightly inbred, was as near to outbred as can be studied under controlled conditions. It had been kept as a closed flock for 10 generations before our study began. The total breeding population of each generation was about 60 cockerels and 750 pullets. As examples of the two types of polymorphism, we studied the *B* blood-group locus, which is extremely polyallelic, as contrasted with three diallelic loci affecting proteins of the egg white (*15*). Unfortunately it was not possible to study the simple diallelic blood-group loci.

Results for the *B* locus partly confirmed the predictions, but also contained some surprises. Four alleles were segregating, giving six heterozygous and four homozygous genotypes. The *B* genotypes of dams showed no association with hatchability. On the other hand, embryos of the various genotypes exhibited marked differences in mortality during incubation. In the first generation studied (*20*), there was general heterozygote advantage, all four homozygotes having higher mortalities than the average for the population. In addition, there were differences between heterozygous genotypes—four being superior with very low average mortality, one intermediate, and one inferior with high mortality.

New and unexpected results emerged when we studied this flock again four generations later (*14*). In addition to the comparison between generations, we were able to compare two substrains, produced by an approximately equal separation of the original flock two years after our previous study. Again, the *B* genotypes of embryos were associated with marked differences in mortality during incubation, but not in the same way as before. The mortalities of five genotypes relative to the population average had changed.

In one substrain these changes were moderate, but in the other they were considerable. Two previously superior heterozygotes were now inferior, while three previously inferior genotypes (one heterozygote, two homozygotes) were now superior. Thus, not only had the relative fitness of various genotypes changed, but also there was no longer any general heterozygote advantage.

These results led us to realize that it was not possible to draw satisfactory conclusions from the situation in one generation. It was evident that the selective pressures on the *B* locus from differential embryonic mortality varied from generation to generation and even between populations (the sub-



strains) differing apparently only slightly in environment and genetic composition. Similar variability may also apply to any association of *B* genotypes with selective values at other parts of the life cycle. The complexity of all these relationships suggests that the B blood groups will not be useful as aids to the identification of genetically superior individuals or families, at least with relatively non-inbred populations.

There is very little published information on any associations of the simple blood-group loci. Our studies (*15, 20*) of the genetically similar egg-white loci did, however, lead to some conclusions which may be relevant. In the same Light Sussex generations and substrains described above, we found that egg-white genotypes of dams were associated with mortality differences of their embryos. As we had predicted, effects were not found at any of the three loci singly, but only when they were considered together in three-way interaction. Specifically, there were marked differences between the mortalities of embryos from dams of the eight triply homozygous classes. In contrast to the B blood-group results, these effects were rather constant between generations and populations. On the basis of these findings, it would seem desirable that any research on possible associations of the simple blood-group loci should be designed so as to study their effects in multiple interaction. Again, no application to practical breeding problems can readily be envisaged.

Associations with Production Traits: Hybrids

IN the preceding discussion, I have advanced reasons for supposing that the blood groups are unlikely to be of widespread general usefulness in genetic improvement. I should now like to describe one specialized situation in which their usefulness is proven. This is the further improvement of hybrid (incross) chickens which have already been considerably improved by other appropriate breeding techniques. It is probable that most of the information on this subject has not been made public by the few firms of large-scale breeders involved, and I can refer to only two published papers.

Allen and Gilmour (*1*) studied the progeny of three-way and four-way crosses of commercial inbred lines of White Leghorns. The matings were so arranged that two heterozygous genotypic classes of female progeny could be compared, namely B^{21}/B^{13} versus B^{21}/B^{14}. In five comparative tests over 4 years, the latter genotype was superior in an index of fitness from hatching to the end of the first laying year. This index was calculated as the arithmetic mean of three components; namely, percent viability while growing (0–160 days), percent viability as an adult in the laying house (161–496 days), and percent hen-day egg production. The superiority was manifested in each of these components.

In contrast to the results from outbreds described above, this effect was consistent over 4 years of testing and in five somewhat different genetic backgrounds. Two unpublished aspects of this work are of interest. First, not all heterozygous classes showed differences. In two tests in 1 year, we found no difference between B^{21}/B^{11} and B^{21}/B^{12} females. Second, we obtained tentative evidence that much of the effect was due to differential susceptibility to disease, in particular the complex of diseases then known as leukosis.

The tests were carried out on numerous co-operating farms (locations) all over the United States, and the results of our published analysis showed that locations had a significant effect on mean fitness. We noticed that the locations fell into two groups—those with considerable mortality (mainly due to leukosis), and those with little mortality. Our unpublished findings were that the difference between the two *B* genotypes was very marked in the high-mortality locations, but hardly evident at all in the low-mortality locations. The obvious conclusion was that B^{21}/B^{14} individuals had a higher resistance to leukosis than B^{21}/B^{13}, but that this could be seen only where there was a high disease incidence.

These unpublished observations of Allen and Gilmour were later confirmed and extended by work published in abstract form by Hansen, Van Zandt and Law (*16*). These authors studied progeny from multiple crosses of some of the same lines we had used, but made a different comparison, namely, heterozygotes of type B^{21}/B^{x} versus B^{19}/B^{x}. (B^{x} signifies one of a small number of possible maternal alleles, and was matched in each comparison.) One specific disease of the leukosis complex was considered, Marek's disease. A marked difference in mortality from 0 to 22 weeks of age was found between the two genotypic classes at locations with a high incidence of Marek's disease, but only a very small difference at low-incidence locations. In di-

rect experiments involving inoculations of day-old chicks with infected tissue, a similar difference in susceptibility was found, the B^{19}/B^{x} chicks being almost twice as susceptible to Marek's disease as the B^{21}/B^{x}.

As regards possible applications to practical problems of chicken breeding, the conclusions of this survey of blood-group research might seem rather discouraging. The two sets of results with hybrids, together with the work on parentage and misidentification described earlier, make up the only firm information on the topic. On the other hand, our own results with the *B* blood-group locus and the three egg-white loci in outbreds, although not obviously applicable in practice, do have important basic implications and suggest some very exciting possibilities for further research. We have briefly considered these matters in the papers cited (*14, 15*), and I hope to deal with them more fully elsewhere.

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A Mixed Verdict for Eutrophication

WHEN nearly 600 bioscientists gathered at the University of Wisconsin's Madison campus in mid-1967 for an International Symposium on Eutrophication, many present regarded the subject as a dirty word and said so. Eutrophication—the biological enrichment of a body of water—too often had been accelerated by sewage to the point where some forms of plant life were flourishing at the cost of rich resources in food fish. (See "Agricultural Drainage and Eutrophication," *Agricultural Science Review*, Vol. 5 No. 4., 1967)

Since that symposium, sponsored by the National Academy of Sciences-National Research Council and several Federal agencies, there has been time for updating of papers and for the meeting's planning committee to review new data as well as meeting statements and to reflect on the full implications of research work presented there. The result is a mixed verdict for eutrophication, extensive research recommendations and a compendium of questions and findings prompting more questions, all brought together in the symposium's newly issued report, *Eutrophication: Causes, Consequences, Correctives.*

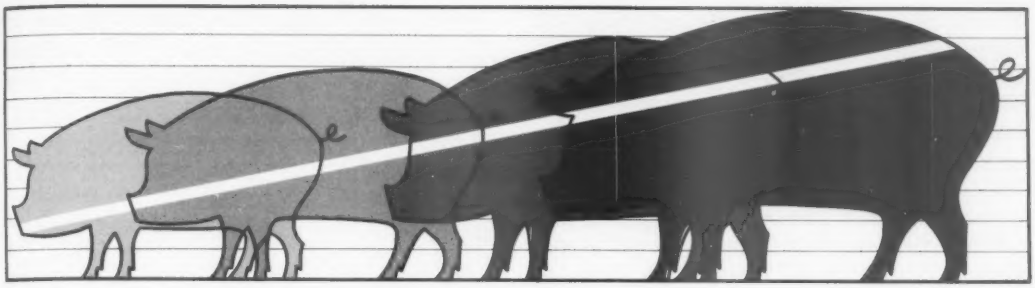
Implications of eutrophication and its end-products for pollution-control authorities seem obvious, as the symposium volume makes plain. Less obvious are other lessons drawn from the symposium. The report observes:

"The notion that chemical enrichment can be desirable is seldom discussed, but this enrichment is precisely what is needed to increase the productivity of marine bays and estuaries. As we consider its effects, we are appalled by the waste involved in sewage disposal. Our first knowledge of eutrophication was derived from efforts to increase production of fish ponds through fertilization. Fish production does increase with fertilization, and in many parts of the world, greater yields are achieved by fertilizing ponds with sewage effluent. However, because of the species changes that typically accompany enrichment, these increases are a major benefit only in areas where the value of fish is determined by weight rather than by species.

"A technology efficient in harvesting macrophytes and plankton and marketing them as useful products would turn eutrophic waters to assets. Almost certainly, however, success would depend on controlling species composition by controlling the nutrient regime."

A review of symposium papers makes it clear, as the volume notes, that greater knowledge of the process of eutrophication is needed and that the study should be approached on "an ecosystem basis," inasmuch as factors accelerating eutrophication originate far from the water's edge.

From: *News Report,*
Vol. 20 No. 1, 1970.
NAS-NRC, Washington, D.C.



GENETIC IMPROVEMENT OF SWINE

Progress and Problems

A. B. CHAPMAN

IN reviewing the literature on heritabilities, repeatabilities and genetic correlations, and on the effects of linecrossing, topcrossing, crossbreeding and selection in swine, one is impressed by the wide variability in the specific values reported for each of these. Yet for each trait, the vast majority of the estimates tend to cluster within a fairly narrow range not only for particular traits but also for specific kinds of traits. Some of these variations in the results may reflect real differences in the genetic and environmental effects. Or, they may be due to differences in methods of estimating the effects, or to random sampling.

GENERAL TRENDS

THE general trends already established by estimates for the effects of mating systems and selection procedures are not likely to be changed markedly by analyses of additional data. This does not mean that these general trends are sufficiently restrictive to exclude truly divergent results from being found and capitalized on if we have the imagination to find them or to modify conditions so that they do occur. For example, the general effects of inbreeding on groups of traits are clearcut and consistent within and even among species. Yet the ways of doing inbreeding and using it have not all been tried, and it may well be that new ways to do it and use it can be found so that more extensive practical use can be made of it.

As pointed out by Dickerson (*5, 6*),[1] it is likely that those traits subjected to unidirectional long-time selection (natural or artificial) would be low in heritability and hence unresponsive to selection. Any genetic variance which remains would likely be nonadditive—including dominance and overdominance—and hence lead to depression with inbreeding. Recovery of lost vigor would be likely to occur from linecrossing within the breeds. With wider crosses, as between noninbreds or inbreds of different breeds, marked hybrid vigor would be expected. The genetic variance of those traits, for which selection does not appear to have occurred systematically over long periods of time, would be expected to contain larger portions of the additive component and hence be responsive to selection and show little effect of inbreeding or crossing.

SELECTION FOR TRAITS

HOW effective is selection for various traits in swine? Insofar as it is possible to evaluate the data

This article is based on a symposium paper given by the author at Madison, Wis., on Mar. 1, 1968.

[1] Italic numbers in parentheses refer to Literature Cited, p. 28.

on selection for those traits already studied, there seems to be consistency between the low heritability of reproductive traits and the ineffectiveness of selection. Likewise, consistency seems apparent between the higher heritability of a carcass trait like backfat depth and the greater effectiveness of selection. For the intermediate heritability traits of postweaning weight, gain, and efficiency, the overall results of selection are unclear. There is good evidence that selection for certain single traits can separate the population into high-gaining and low-gaining lines (*13*) and into high and low efficiency-of-feed-utilization lines (*8*). Results from other experiments (*3, 9, 10*) show that selection for rapid gain or high 154-day weight is considered to have been effective. But in contrast to this, results of research with 47 lines at 7 State experiment stations (*7*) point to a loss of approximately 3 pounds in 154-day weight per year when a gain of 2 pounds was expected on the basis of the selection practiced. It is not known how much of the difference between observation and expectation and between experiments is due to the differences in the genetics and environment of the stock, the inaccuracy of adjustment for confounding influences such as inbreeding and environment, or chance fluctuation.

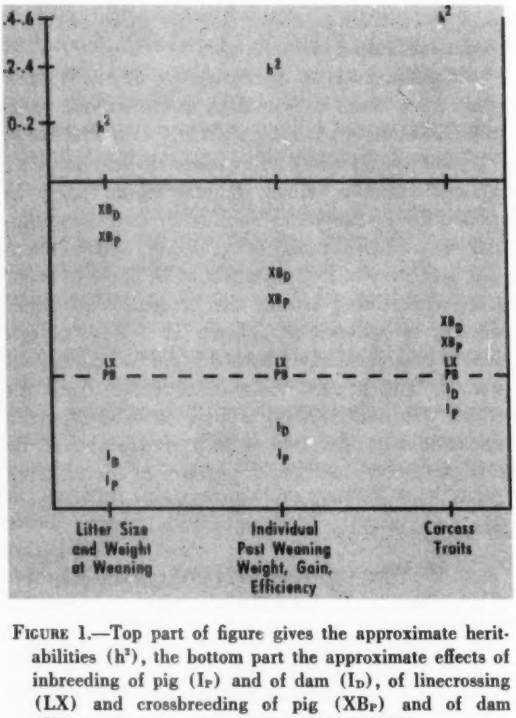


FIGURE 1.—Top part of figure gives the approximate heritabilities (h^2), the bottom part the approximate effects of inbreeding of pig (I_P) and of dam (I_D), of linecrossing (LX) and crossbreeding of pig (XB_P) and of dam (XB_D), relative to non-inbred purebreeds (PB).

Figure 1 depicts some of these relationships in that the heritabilities (upper part of figure) of litter size and weight at weaning (naturally selected traits) are low, the effects of inbreeding of pig and dam (lower part of figure) are large as are the effects of crossbreeding. The other end of the scale, carcass traits (apparently of little adaptive value), shows high heritabilities and only minor effects of the various mating systems. Post-weaning weight, gain, and efficiency of feed utilization are traits which have heritability values and effects of mating systems which are intermediate between the productivity and carcass traits and are thought of as intermediate in adaptive value.

One of the clearest demonstrations of the effectiveness of selection is found in experiments on selection for live-animal backfat depth in swine (*12, 14*). Typical of these results are those of Hetzer and Harvey (*12*) shown in figure. 2.

The upper half of the graph shows the results of 10 generations of mass selection for high (D-H) and low (D-L) live-animal backfat depth at a weight of about 79 kg. in Duroc swine. Backfat depth of the unselected control (D-C) pigs is also given. Comparable data are presented in the lower half of the graph for eight generations of the control line (Y-C) and of selection for high (Y-H) and low (Y-L) backfat depth in Yorkshire swine. The differences between the high and low lines in both breeds over the 10 and 8 generations of selection is 4.7 and 4.6 times the standard deviations in the respective foundation stocks. These differences represent realized heritabilities (regressions of generation means on cumulative selection differentials) of 0.47 and 0.48 for the high- and low-fat Duroc lines and 0.38 and 0.43 for the high- and low-fat Yorkshire lines.

When selection is practiced for certain traits, it is important to know whether they are genetically correlated with other traits. Dickerson (*4*) concluded that rapid fat deposition, low feed requirement and poor suckling ability tend to be genetically associated. Fredeen and Johnson (*11*) present results supporting the view that decreased

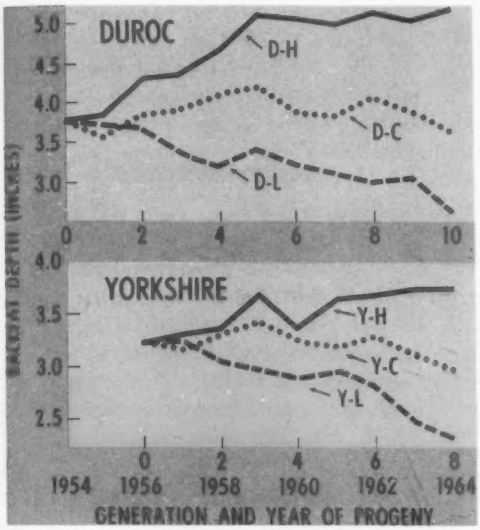


FIGURE 2.—Generation means of selected and control lines—Hetzer and Harvey (*12*).

fat deposition and lower feed requirements are genetically associated. Bradford *et al.* (*1*) point to a negative association between the additively genetic effects in the pig for rate of gain and maternal effects as reflected in the differences among inbred lines. Other cases of positive and negative genetic associations have been cited. By and large, however, the evidence shows that the genetic relationship between the most important traits in swine seems to be favorable; or they are sufficiently close to independence genetically that this phenomenon should not, at least, be a major drag on selection.

BASIS FOR DECISION MAKING

THE basis for decision as to the most effective practical way to bring about genetic improvement in swine involves not only information on estimates of sizes of genetic parameters for economically important traits, but also of a variety of other factors: the relative economic values of these traits, the best methods of measuring them, the extent to which accurate information can be collected on the farm (including farmer acceptance), the facilities available for central testing, the opportunity for performance testing of boars at a central testing station, the practicability of getting carcass data on part of the testing station boars as well as on barrows, the cost of these record-taking schemes relative to the genetic gain coming from them, and other economic and sociological factors important in developing programs involving private ownership. If estimates of the role of these factors have been made, it then becomes necessary to ask how available on-the-farm facilities and central testing station facilities can best be used to assess genetic make-up so that selection will maximize genetic improvement per unit of time.

A number of studies have been directed toward estimating the relative value of records on individual performance, progeny testing and sib testing for different sized herds, for different numbers of animals and litters tested, for different numbers required for replacement, for different numbers of males under progeny test and considering different amounts of genetic and environmental variation and different degrees of genetic and environmental association between family members.

I do not claim to have weighed all of these biological statistical and socio-economic problems correctly and to have extracted the optimum scheme for the genetic improvement of swine. In general, however, I conclude that it would be wise for the purebred breeder to keep on-the-farm records on (*a*) the productivity of his sows, (*b*) the post-weaning gain or weight for age or number of days to reach market weight of his pigs, (*c*) live animal backfat thickness, and (*d*) the occurrence of abnormalities. These records could then be used as intraherd-mate contemporary comparisions, preferably in selection index form, for selecting replacements and for deciding which animals to send to a central testing station. The major purpose of the central testing station could be performance testing of boars and their litter mates for gain and obtaining information on efficiency of feed utilization and live-animal backfat depth or other carcass information. Progeny testing would occur automatically but would not be the primary objective. Litter mates of the boars and the poorer boars themselves could be slaughtered for carcass data. Superior boars should be placed in herds where records can be made available on their progeny from on-the-farm and central testing station information.

For the commercial producer the clearcut advantage of crossbreeding—particularly for reproductive traits—would argue strongly for crisscrossing; that

is, alternating the sires of the two breeds each generation and mating them to the crossbred gilts, or for rotational crossing in which a cross of two breeds is followed by use of the sire of a third breed on the crossbred sows. The progeny of these would be bred to a sire of the same breed as the foundation females or a sire of a fourth breed would be introduced. The limit to the number of breeds involved would be set by the availability of superior boars and the size of the herd being crossed. Boars used by this segment of the industry should, of course, be selected from on-the-farm and centrally tested stock. On-the-farm records should also be maintained by these commercial producers as a basis for selecting superior female replacements.

With further expansion of artificial insemination in swine, boars that are deemed superior should have realistic intraherd contemporary comparisons made on their progeny out of a variety of dams and raised in a number of herds. This progeny test information would be the basis for picking out boars of the highest merit from those which had been selected originally as superior by on-the-farm and testing station information. Dissemination of the inheritance of the optimum numbers of these highly superior boars could then be readily accomplished by further artificial insemination.

RESEARCH MISSIONS

TWO kinds of research need to be emphasized in our current programs.

Research in the Field

WE need to tie together what we now know, think we know, or would like to know, into an overall investigational program to accomplish three things: (1) to learn if we are right in concluding that certain procedures are actually superior to others when used in a full-scale farm selection program; (2) to get the facts on procedures for which we do not even feel we have the information at the present time; and (3) to present in completely organized and, hopefully, close to unequivocal form a demonstration that neither the practitioner nor the theoretician can honestly argue is "unproven" in any of the contexts normally used for support of a chosen point of view.

My approach to this would be to work in close cooperation with a number of breeders who are willing to:

a. Collect, or have collected by research and extension personnel, on-the-farm records on productivity, growth, and backfat on all their animals.

b. Submit samples of their animals (boars and their sibs) to a central testing station at which representatives of the other herds in the program are also being fed out to get information on efficiency of gain and carcass quality.

c. Have conformation and type scores, which reflect show-ring standards, placed on all the animals in the herd and at the testing station.

d. Allow progeny testing by artificial insemination of selected boars on which on-the-farm and testing station information is available. The progeny testing of each boar should be done on several farms from which full information on productivity, growth, and backfat depth will be made available and from which samples of the pigs will be taken to a central testing station for evaluation of efficiency, growth, and carcass quality.

e. Allow, in addition to collection of information on straightbreds, collection of similar information on crossbred progeny of the same boars.

The question which would then be asked of these data is: What is the relative importance of each of these methods of boar evaluation (separately and in varying combinations) in terms of their predictability of the efficiency of production of consumer products by his progeny? Efficiency of production of consumer products may be defined by an economic index made up of the pounds of quality pork produced relative to an estimate of the cost of production per litter of pigs raised to market weight. Included in this estimate would be the cost of raising and maintaining the sow as well as her litter.

A balance sheet, giving the relative importance of these several variables singly and jointly, should yield a fair and impressive evaluation of the merits of on-the-farm and testing station information—including the conformation and type reflection of show ring standards.

It is hoped that the results from this approach not only will provide the necessary facts but will yield them in a form that can be readily understood and appreciated by laymen and specialists. If so, the stage should be set for wider acceptance of correct procedures. Purebred and commercial breeders who have been cooperating in this work should benefit directly from the information made available to

them by the program. At the same time they will have a mechanism set-up for further advancement and could become leaders in adopting and demonstrating correct procedures for genetic improvement of swine.

Research at the Experiment Station

IN a slightly more distant future unpredictable changes, in feeding and management policies and in the kind of product the market demands, call for research which leads to a basic understanding of the processes underlying the variation in the productive and reproductive traits of swine. This deeper knowledge of underlying causes should allow us to mold our stock more readily to whatever the rearing conditions and market might demand.

There are many areas in which research of this kind is called for, and it is difficult to decide which ones should have priority. One of the approaches we use at the University of Wisconsin represents an attempt to coordinate various facets of the overall problem, such as patterns of development of a number of traits concerning male and female reproduction, efficiency of feed utilization, carcass traits, and learning ability. We are using four genetic groups (two breeds and their reciprocal crosses) and two environments (full and limited feeding) within which these traits are being studied. This research is being done cooperatively by a team of research workers who are specialists in each of the areas listed. Each one is doing his research with animals that come from the same genetic and environmental backgrounds.

The plan is to examine variations in the developmental patterns of these traits in the light of the genetic and environmental differences which occur among the different breeding and feeding groups and also within them.

All of the cooperators have participated in the planning of the experiment and will be kept up-to-date on developments in each facet of the experiment. Presumably, the results found in one area of research will aid in understanding the results in another. Thus, the overall characterization of the effects of genetic and environmental factors on development will, hopefully, occur.

COOPERATIVE EFFORTS

THE complexity of swine breeding problems, whether at the level of research or application, leads one to conclude that their solution resides in realistic cooperative effort at all levels of operation.

Some of the benefits to research from capitalizing on information from different disciplines in the design, conduct, analysis, and interpretation of an experiment have just been detailed. Cooperation between extension and research personnel can also be helpful by providing the extension worker with a fuller understanding of what is available for application to swine breeding and how it might be applied. Moreover, such cooperation also keeps the research worker aware of problems in the field and provides help in getting research data from the field.

Cooperation between the swine breeder and the research worker can also be mutually beneficial. As pointed out earlier, the use of the breeder's stock and the conditions under which they are raised add practical facilities to the research opportunities of an animal breeder (2). Thus, the researcher keeps in closer touch with the actual problems of animal breeding at the farm level. Cooperative effort also keeps the swine breeder abreast of new breeding knowledge through contact with research and extension workers and through his own observation of the results from the experiments in which he is a cooperator.

Swine breeders, too, can profit by cooperating among themselves in setting up testing programs and then utilizing fully any superior stock developed by this group effort. Furthermore, cooperation between the purebred and commercial producer will allow producers of seed stock to evaluate their sires in terms of the performance of their progeny from commercial dams. The need for detailed information on prospective boars for A.I. organizations and on progeny tests of those boars in service calls for cooperation between the A.I. centers and their clientele.

If the swine industry is to arrive more surely and more rapidly at solutions to its mutual problems, cooperative effort is going to have to play a more realistic role in the future than it has in the past.

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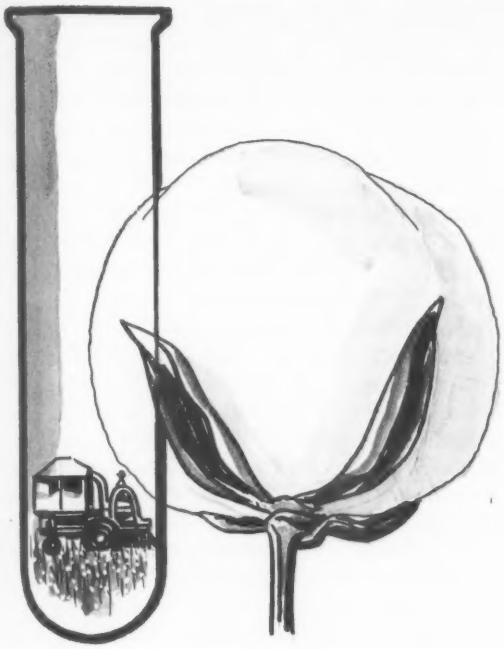
Monday Morning Research

COOPERATIVE research by home economists from six universities in the West (Arizona, California, Colorado, Hawaii, Nevada, and Oregon) has showed that the use of hot water for laundering white cotton fabrics was superior to that of cold water. Factors studied included soil removal, fabric whiteness, softness, strength, shrinkage, smoothness, and cost.

After a series of soilings and launderings, results of the tests showed that:

- Substantially more soil was removed by hot-water laundering than by cold-water laundering.
- Of the two detergents used, the regular granular hot-water detergent was more efficient in soil removal at both temperatures than the liquid cold-water detergent.
- Samples washed in hot water with granular hot-water detergent rated highest in fabric whiteness; those washed in cold water with a cold-water detergent rated lowest.
- Fabrics washed in hot water were smoother and softer; detergent type had no effect on these factors.

—Condensed from an article in *Nevada Ranch & Home Review,* Vol. 4 No. 6, 1970, by B. Jean Margerum.



COTTON INSECT RESEARCH

A Case Study of the California Program

IN 1969 the California Agricultural Experiment Station decided to take a hard look at its cotton research program by directing the attention and study of a task group on the current efforts and on the problems that seemed certain to plague the State in the future.

In selecting the members of the group, Director C. F. Kelly was guided by the conviction that those best qualified to evaluate research are the researchers themselves and those who directly benefit from research. Accordingly, he appointed a task group made up of California cotton producers, researchers from various disciplines in the experiment station and the U.S. Department of Agriculture, and several Extension specialists.

The report, which was published late in 1969, is the first of several in a series. Additional task groups are being formed to evaluate research on mechanization, solid waste disposal, avian pests, and other areas. For a number of reasons, the entomological section of the present report merits adaptation and publishing in *Review*.

In the first place, the pest control situation as described would be applicable to all of the cotton-growing area west of Texas, which produces 25 percent of U.S. cotton. Moreover, some of the principles and research approaches discussed—for example, that insect control is an exercise in applied ecology—might well be considered for adoption in other cotton-growing areas of the world.

Second, the matter of accurately assessing the adequacy of research programs dealing with cotton insects was never more important or timely than it is today—particularly in view of the changing pesticide regulatory directives. And for some growers, the highest ranking cost in terms of percent of dollars spent per acre is that of insect pest control.

Third, it could be argued that this case history encompasses more than just the research problems within the borders of a single State. For, as Task Group Chairman Thomas Leigh points out, cotton production is at a critical crossroads. Yields are no longer escalating with each innovation; production costs are rising and competition is becoming keener.

From a broader viewpoint, research institutions need all the encouragement they can get in setting up patterns of interdisciplinary work. In that re-

spect, the California programs offer ample evidence of how unrelated disciplines are working together to meet a major problem.

The report follows:

History

THE earliest recorded cotton insect research in California dealt with a lygus bug problem in the Imperial Valley. A solution was not found and the lygus bug problem, along with outbreaks of the cotton leaf perforator and stinkbugs and an era of depressed prices, led to the cessation of cotton production in the lower desert valleys for many years.

The cotton insect research project of the California Agricultural Experiment Station was initiated in the late 1930's following 3 years of severe stinkbug outbreaks. This program has been expanded in recent years to include studies of chemical, biological and cultural control of the arthropod pest complex.

Effective pest control programs were first developed during the 1940's through introduction of DDT and several other synthetic organic insecticides. These materials provided outstanding control of pests such as lygus bug and bollworm, but their use also resulted in severe outbreaks of spider mites and several other pests that had been of relatively little importance prior to that time. The result has been a more intensive pest-control research program which today is very broad in its approach. Present research programs are oriented around evaluation of pesticides, the biology-ecology of the pests and their natural enemies, biological control, host plant resistance, and cultural management for suppression of insect pests.

Recent Accomplishments

INTENSIVE studies on *Lygus hesperus* have provided considerable information on its life history, its bionomics, its natural enemies, the nature of its injury to cotton, its economic importance and methods for its chemical and cultural control. Among the most important findings are that alfalfa is a major reservoir of *Lygus;* that *Lygus* migrations from alfalfa into cotton can be prevented by strip culture of alfalfa; that *Lygus* which migrate into cotton from alfalfa, for the most part, move quickly back into alfalfa; and that *Lygus* is perhaps a less serious pest of cotton than previously had been suspected.

Bollworm studies have been greatly intensified in recent years. Significant findings include: A better knowledge of seasonal flight patterns of bollworm moths; precise information on distribution of bollworm larvae in cotton fields and on individual cotton plants; refined bollworm sampling and damage assessment techniques; a measure of the impact of field populations of predators on bollworm eggs and larvae; a knowledge of bollworm parasites and their relative importance; status of diseases in field populations of bollworm; and the degree of bollworm resistance to several insecticides.

One of the most important accomplishments in over-all management of cotton pests occurred in southern California, where a widely practiced integrated control program resulted in a greatly diminished pest problem and considerable reduction in pest-control costs. Under this program the cotton leaf perforator, cabbage looper, salt marsh caterpillar, spider mite and several other secondary pest problems were strikingly reduced and the bollworm problem was greatly alleviated. Unfortunately, recent heavy insecticide programs directed against pink bollworm have disrupted this favorable situation.

Present Status

INSECT pest control on cotton is one of the important factors in efficient cotton production. Without adequate pest control, the benefits of research for improved cotton production developed by other scientists may be partially or wholly lost. Recent losses to insect pests in yield and quality, plus chemical control costs, are variously estimated to be as high as 25 to 35 percent of the potential net income to the grower. While cotton prices have remained stable (1967 is an exception), production costs have spiraled and pest problems have been triggered to a point where efficient insect control is now in jeopardy in many areas of the state. If current attitudes and control practices continue, there is every reason to believe that the situation will worsen. In fact, the pest-control problem seriously threatens the entire cotton industry in California.

In the foreseeable future, control measures will still rely heavily upon insecticides as a final defense for most pest problems. However, the untimely, ill-advised and even indiscriminate use of chemicals, applied largely because of uncertainty, has placed

cotton production in a serious position. Long-range research programs must seek greater sophistication in the development of alternate controls plus a more accurate determination of economic injury levels, and this knowledge must be combined with selective chemicals for better pest management on cotton.

It is now evident to researchers, though apparently less evident or acceptable to some growers and the chemical industry, that insect control is an exercise in applied ecology. In order to solve or relieve the current situation, a reevaluation of research goals, as well as a change of attitude toward the use of insecticides, is needed by some growers and the chemical industry. These research aims and attitudes must be oriented to the development and grower-utilization of integrated control programs designed for different cotton areas and pest complexes.

The purview of integrated control is broad and includes utilization of all pest-control techniques in a compatible manner so that the use of one does not disrupt another but rather supplements, or achieves better results than, any one method. Chemical, cultural, and biological controls, resistant varieties, and sterile male techniques are all included.

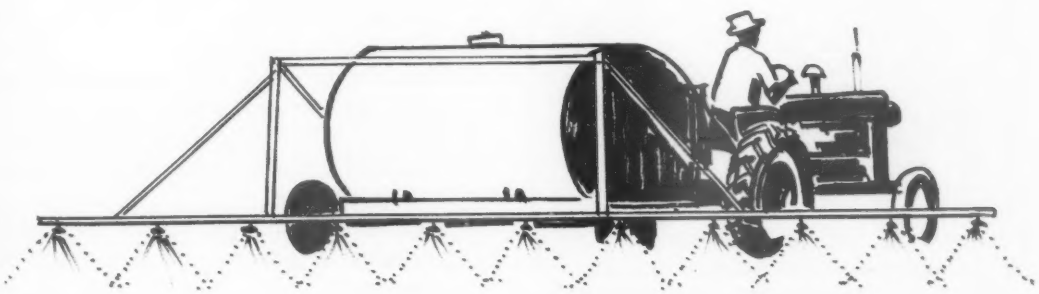
Although cotton may be attacked by a variety of pest species, there are, in fact, three key insect pests: the bollworm, *Heliothis zea* (Boddie), the lygus bug, *Lygus hesperus* (Knight), and the pink bollworm *Pectinophora gossypiella* (Saunders). We believe that methods of controlling them which are of minimal disruptiveness to the ecosystem can be developed. Through such an ecological program, most other cotton pest problems may well be markedly reduced, and, moreover, selective or ecological control of one or more of the three key pests can contribute to the control of the others. For example, cultural control or suppression of *Lygus* will markedly reduce the need for early season insecticide treatments, and this will permit natural enemies of the bollworm to survive and exert their maximum effect on that pest. Thus, it is important to take into account the impact that control methods for one species might have on another.

Future Research

THE research needs of the entomology program are not readily divisible into short and long term studies. Pesticide evaluation and some biological studies may provide early answers to critical problems. However, pesticides have long term implications through their effect on the biota in the field; thus most entomology research is of long term nature, although contributions to the immediate problems are often made.

Although more than 20 pests may attack cotton, the research program is centered around three insects and (to a lesser extent) the spider mites. Other pest problems necessarily receive attention as they occur. Research needs for the key pests are as follows:

Bollworm, *Heliothis zea* (Boddie)—The bollworm causes major direct and indirect losses to cotton production. The pest's wide host range, plus other factors, adds greatly to the problem. Under favorable circumstances various natural enemies tend to keep bollworms below economic injury levels, but under other circumstances (not all of which

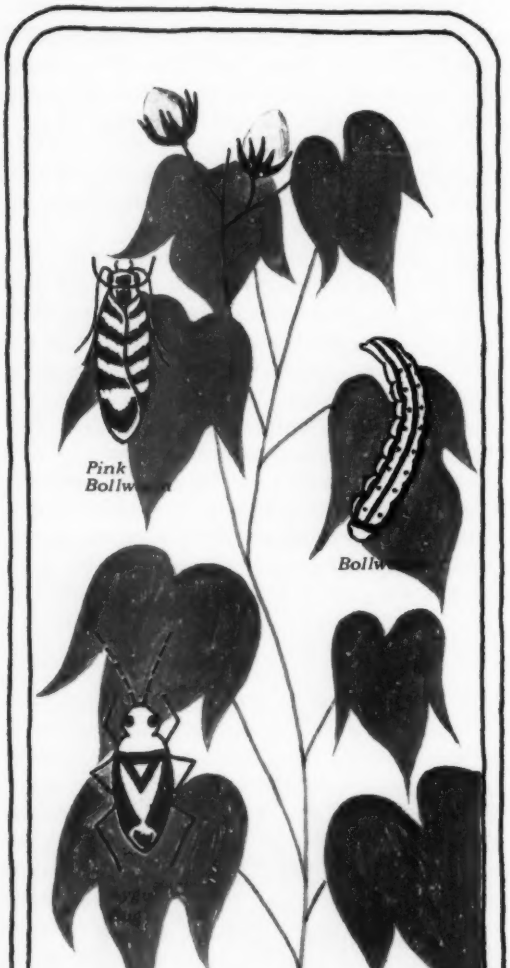


are understood) bollworms may cause widespread damage. In particular, early season insecticide applications for *Lygus* control can so upset the natural balance that bollworms may later increase to levels requiring repeated and costly control measures which at best are not highly effective. Thus, one of the greatest contributions to bollworm control will be realized when early season *Lygus* treatments can be eliminated or markedly reduced.

A number of other techniques and practices aimed at reduction and management of bollworm populations also are needed. Low cost biological, chemical, cultural, and other methods that can be employed alone or properly integrated must be developed to achieve effective and economical bollworm control without contributing to environmental disruption and pollution.

Specific research needs include:

- Investigations of seasonal development of the bollworm on various cultivated and wild host plants, and an appraisal of the extent to which each major host contributes to bollworm populations in various cotton-growing areas.
- Reappraisal of the damage potential of bollworm populations in order to establish reliable economic injury levels, so that the need for insecticide or other treatments can be determined with precision.
- Search for effective and selective chemicals and their proper integration with biological and other control methods.
- Analysis of the role of parasites, predators and diseases in controlling bollworms in various areas, the augmentation of these natural enemies, and investigation of the mass release of parasites and predators and the effective use of microbial materials for the direct control of bollworms.
- Investigation of the response of bollworms to physical stimuli (such as light and sound) and an appraisal of their potential as tools for forecasting outbreaks (e.g., with light traps) or in the practical control of the pest.
- Accumulation of necessary information on the population dynamics of *H. zea* as a basis for appraising the feasibility of using the sterile male method for keeping bollworms below economic injury levels.
- A study of bollworm overwintering and factors that may contribute to survival of the overwintering forms.
- Collaborative efforts with plant scientists to search for bollworm-resistant germ plasm in cotton, and the determination of the usefulness of bollworm-resistant varieties in the reduction of crop losses.
- Expansion of cultural method and crop management practices to reduce bollworm infestations.



- Investigation of the basic physiology and nutrition of the bollworm in an effort to develop new approaches to control, and to accumulate information that will make feasible the mass rearing of bollworms for use in the large-scale propagation of parasites, predators, and diseases or as stock for production of sterile males.
- Thorough analysis of data emanating from USDA labs and other experiment stations, and the adaptation of those techniques that are amenable to California conditions.

Pink Bollworm, *Pectinophora gossypiella* (Saunders)—The pink bollworm is not the most costly of the key cotton pests, as it is still largely or wholly restricted to southern California where only about 10 percent of the cotton is grown. Nevertheless, it has the potential of becoming California's major cotton pest. Its detection in the southern San Joaquin Valley late in the 1967 growing season, in spite of heavy insecticide treatments in the desert valleys, showed how rapidly this pest can spread. This insect not only can greatly reduce yields and sharply increase control costs in the desert valleys, but wide-scale treatments for its control have greatly complicated other pest control problems. The cotton leaf perforator, for example, is normally under good biological control for most of the season in Imperial Valley, but its outbreak in 1968 illustrates complications caused by pink bollworm control practices. In addition, the extremely high populations of pest species on other crops in the fall of 1968 appear to be directly related to the control practices for pink bollworm on cotton

In July 1968, a research program was established by the University of California and the U.S. Department of Agriculture with the ultimate objective of developing control practices which are effective and economical for control of this pest. This program was made possible largely through financial assistance of the cotton industry in the state of California. Some of the most important lines of research needing attention are:

- Investigation of the biology, behavior, ecology, and seasonal population development of the pink bollworm.
- Utilizing information developed from the preceding for modification and adoption of cultural control practices used in other areas in the United States to make them effective for California conditions. As presently utilized they have proved helpful but inadequate.
- Development of safe, economical and effective insecticides which can be used to supplement other control or eradication measures. One insecticide found in 1968 is very effective on pink bollworm and did not develop undesirable secondary problems in the cotton. It appears to be somewhat selective; at least it is relatively nontoxic to honeybees. This material is not registered for use in cotton at this time.
- Thorough investigation of the role the pink bollworm sex attractants can play directly in control and eradication programs, or indirectly by providing reliable means of forecasting the need for chemical treatments.
- Development of a program to utilize native or introduced biological agents in the control of the pink bollworm. Present funding does not support this research work.
- Assisting the U.S. Department of Agriculture in determining the role sterile pink bollworms can play in preventing the spread of the insect to new areas, in the elimination of incipient or naturally low infestations, and in investigating the feasibility of employing sterile pink bollworm moths for eradication or area-wide control when integrated with successful cultural, chemical and biological control procedures.
- Searching for pink bollworm-resistant germ plasm, and an assessment of the usefulness of resistant cotton varieties in pink bollworm control.

These are the major lines of research, and most of them are underway. Some segments of the research program (such as that on insecticides) should prove useful in the foreseeable future. Other and more desirable measures in the long run are complex, and will require considerable development for widespread adoption by the cotton industry.

Lygus bug, *Lygus hesperus* (Knight)—Lygus can cause appreciable damage to cotton when they are abundant, particularly during the early fruiting period; however it may not be as generally serious a pest as it has been thought to be. Control has been almost completely dependent upon insecticides, but many treatments are probably unnecessary and this has helped create serious problems. For example,

short-lived, broad-spectrum pesticides often cause wholesale destruction of beneficial insecticides, thus releasing different pest species from their biological control. These pests may then rapidly increase to dangerous levels. It is vital, therefore, to assess the true injury potential of *Lygus* and to develop alternative control methods and selective chemical controls that do not engender serious secondary problems.

Specific research needs include:

- Establishment of sound criteria for estimating the economic injury level of *Lygus* on cotton and the development of more sophisticated methods of control. The currently utilized economic threshold for *Lygus* appears to be obsolete. One of the most urgent needs in the California cotton pest situation is a re-evaluation of the status of *Lygus* as a cotton pest and the establishment of new (more flexible) economic thresholds.
- Development of selective insecticides which will achieve adequate results in emergency situations without upsetting the beneficial insect complex, and which will replace compounds to which resistance is developing.
- Investigation of the various natural enemies of *Lygus* to determine practical ways of using them for practical control.
- Analysis of various methods of culturing alfalfa so it will function as an attractant and "trap crop" for *Lygus*.
- Study of safflower harvesting and management techniques to reduce or prevent dispersal of *Lygus* into adjacent cotton growing areas.
- Investigation of *Lygus* resistance in cotton and the incorporation of such resistance into agronomically satisfactory varieties.
- Development of mass production methods for *Lygus* to provide material for various studies, including the feasibility of mass producing parasites or predators for use in biological control.

Spider mites (*Tetranychus atlanticus* McGregor, *T, urticae* (L.), *T. pacificus* McGregor)—Intensive research has indicated that spider mites are normally controlled by a complex of predators. Outbreaks are rare except when pesticide use upsets the predator balance. Traditionally, where spider mite outbreaks have occurred they have been controlled with effective miticidal compounds. However, spider mite resistance to miticides has and will continue to occur and new methods of control must be developed.

Specific research needs include:

- Development of new compounds that will provide control without disruption of the biotic environment.
- Investigation of the various natural enemies of spider mites to determine how their role can be enhanced.
- Development of cotton varieties tolerant of or resistant to mites.

DDT (*Continued from page 12*)

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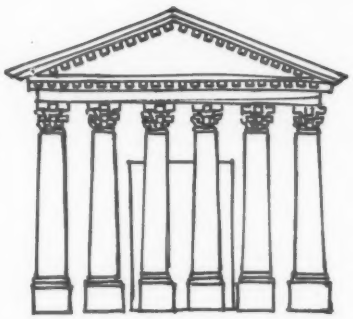

FORUM

NURSERY STOCK PRODUCTION AT THE CROSSROADS

DURING the past 100 years, the technique of growing reforestation material has undergone several radical modifications. Most of these were aimed at preservation of the young plants and lowering the production cost.

Originally, tree planting stock was raised in small, temporary nurseries established on land deforested for that purpose. Upon exhaustion of the soil nutrient supply, or invasion of the area by parasitic organisms, the nursery was transferred to another recently cleared patch. This method was not well adapted to large scale reforestation, but it usually provided stock of high growth potential.

Reforestation of large acreage of cutover lands required many millions of young trees and brought into existence large permanent nurseries. A continuous drain of soil nutrients in such nurseries was corrected by adding fertilizers. The drought loss of trees was precluded by installing artificial watering. Thus, the survival potential of stock produced in these nurseries could vary widely depending on the method of irrigation and fertility maintenance.

The discovery of potent biocidic compounds revolutionized nursery practice, and considerably reduced the destruction of plants by parasites and the cost of weed eradication. However, the introduction of eradicants imposed on nursery management an extremely difficult problem: production of unharmed young trees in the soil in which weeds, parasitic fungi, and injurious insects were exterminated by poisons.

Aside from the direct injury to trees, many eradicants exert a hormone-like stimulating effect which imparts to planting stock unreasonably large crowns of succulent structure. On the other hand, the toxicity of applied and residual biocides depresses the development of the root systems, especially their downward penetration. The combined influences can result in planting stock of extremely unbalanced top-root ratio. A large number of biocides exterminate or temporarily immobilize mycorrhizal fungi and the extra-matrical, chelate-producing microorganisms essential for the uptake of certain nutrients, particularly phosphorus. Depletion of organic matter, occasional over-watering or over-fertilizing, absence of microbial competition for nitrogen, conversion of some chemicals into reduced toxic compounds—all contribute to the production of morphologically and physiologically unbalanced reforestation material vulnerable to drought, frost, winterkill, snowpress, and parasitic organisms. The time may not be far away when Henrik Ibsen's observation will be applicable in a very slight paraphrasing:

> "Withered trees
> Not in vain you were begotten;
> As compost you'll serve
> When rotten . . ."

The deteriorating influence of prolonged use of biocides on the quality of tree planting stock can be demonstrated readily by ordination analyses. However, no analyses are required to arrive at the conclusion that extermination of undesirable forms of life by toxic compounds and production in the same soil of unharmed plants cannot be accomplished without special amendments. Satisfactory

development of trees on biocide-treated soils demands the introduction of certain adjusters of soil productive capacity.

These adjusters are very recent developments of urgent necessity; their number is rather limited, but very likely can and will be increased, for at times they may play the role of "life savers" of nursery establishments.

Substantial improvement of planting stock already has been achieved by the use of a few compounds. For example, the excessive development of seedling crowns was reduced in some instances by applying aluminum sulfate, a strongly acidifying agent which diminishes the release of available nitrogen. In other cases, the same chemical considerably elongated the root systems, perhaps by removing the residual biocides from the subsoil. A somewhat similar effect, leading to an improved top-root ratio, was produced by deep incorporation of strongly acid moss peat mixed with raw sawdust. Adding a small amount of allyl alcohol produced in some soils an abundant re-invasion of *Trichoderma* fungi and subsequently increased the availability of phosphorus in mycorrhiza-suppressed soils treated with a dithiocarbamate. By far the most effective revitalization of the microbiotic mechanism in biocide-treated soils was achieved by *Coprinus* fermented sawdust compost sprayed with a leafmold suspension. Paradoxically, the morphology of trees raised with highly stimulating biocides was significantly improved in some cases by applying fertilizers which exerted additional stimulation of the crowns as well as the root systems. In turn, the treatment greatly diminished top-root ratio and corrected the internal nutrient balance of the trees. There is little doubt that in many instances the deteriorating effect of eradicants is aggravated greatly by a deficiency of soils in some essential nutrients.

Continuous analyses and readjustment of the productive capacity of nursery soils by applying fertilizers, re-innoculating materials, antitoxins, growth-retarders, etc., requires a great deal of extra work and considerable expense. In plain language, the contemporary nursery practice is in a predicament; it is in the position of the legendary knight standing at a crossroad with signs indicating the directions to different kinds of perils. The choice is either to meet the chemotherapeutic dragon or to divert the journey to an unmarked road. Some foresters believe that the weed and parasite menace can be avoided by the use of biocide-free hydroponics. The Finns are experimenting with the culture of individual potted seedlings in plastic greenhouses. The Russians place hopes on direct seeding.

None of these side trails are free from obstacles which are particularly great in countries with high labor costs. But, if worse comes to worst, the road back is not blocked, that is, the road to the small, temporary nurseries on recently cleared lands. The retreat will lower the output, but will have one indisputable advantage: Young trees will receive well-balanced, additive-free nourishment, supplied by the supreme dietician—nature.

S. A. Wilde,
University of Wisconsin

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THE AUTHORS

JOEL BITMAN is Leader, Hormone Physiology Laboratory, U.S. Department of Agriculture, Beltsville. He did his undergraduate work at Cornell and received both his M.S. and Ph. D. degrees from the University of Minnesota. Aside from a two-year term at Columbia University, he has been on the USDA research staff since 1951. Dr. Bitman's special fields of interest include the chemistry and metabolism of sex hormones, vitamin A deficiency, and the mechanism of estrogen action.

ARTHUR B. CHAPMAN ("Genetic Improvement of Swine") is professor of genetics, College of Agricultural and Life Sciences, University of Wisconsin, Madison. A native of England, he holds degrees from Washington State and Iowa State, and received his Ph. D. in genetics from the University of Wisconsin in 1935. He joined the Wisconsin staff in 1937. He has served as president and director of the American Society of Animal Science, also as editor of its journal. In 1969 he received the Animal Breeding and Genetics Award of this society. Dr. Chapman has served as a consultant and lecturer on animal genetics in several foreign countries, and has made notable research contributions in the field of animal genetics by his experiments with livestock and the laboratory rat.

DOUGLAS G. GILMOUR ("Blood Group Research in Chickens") has been director of the genetics laboratory, Department of Psychiatry, New York University School of Medicine since 1965. A native of England, he was educated at the University of Cambridge (B.A. 1942, M.A. 1945, Ph. D. 1949). In 1945 he joined the faculty of the School of Agriculture, University of Cambridge, where he taught courses in physiology and in animal breeding and genetics, and from 1957–65 was also director of the Poultry Genetics Research Station at the University of Cambridge. He has twice been awarded fellowships enabling him to spent sabbatical leaves in the United States. He has served as advisor on blood group research to research laboratories set up by a number of foreign governments and universities, and by some commercial poultry breeders in both England and the United States.

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